PASTORAL AND AGRICULTURAL BOTANY

HARSHBERGER

Frontispiece.—Case 536, July 9, 1906. A locoed steer poisoned by having eaten stemless loco-weed (*Aragallus (Oxytropis) Lamberti*). Note the swelling and the curvature of the fetlock joints, which is peculiar to some locoed animals; the rough coat, staring eyes. In the last stage, the animals eat and drink very little. After ***Marsh C. Dwight:*** The Loco-weed Disease. Farmers' Bulletin 1054, Fig. 10, page 14, July, 1919.

TEXT-BOOK OF

PASTORAL AND AGRICULTURAL BOTANY

FOR THE STUDY OF THE INJURIOUS AND USEFUL PLANTS OF COUNTRY AND FARM

BY

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PREFACE

During and since the great world war there has been a growing demand for information on the injurious and useful plants of America. The injurious plants are represented by those belonging to the lower phyla, the thallophytes, which include the fungi, destructive to farm crops, and the higher flowering plants, which are some of them also injurious. In the following pages, particular attention will be given to the flowering plants with casual mention of the flowerless forms, which come within the purview of this book. The contents of the pages, which follow, epitomize the laboratory and research work of the writer connected with a course in botany given to the veterinary students of the University of Pennsylvania for the past twenty-five years. The course has been given during the college year for two hours per week, one lecture and one laboratory hour. The first term (October to February) is devoted to a study of the general morphology and physiology of plants, and the second term (February to June) to the consideration of the plants (injurious and useful) of economic importance. The laboratory exercises supplement the lectures. The injurious plants are considered first, because they lend themselves peculiarly to indoor laboratory work of a technical kind, which can be pursued in the northern states, while wintry conditions prevail out of doors. Then too, professional students are anxious after the preliminary work has been given, such as the morphology and physiology of plants, to start at once upon the part of botany which applies directly to the scientific preparation for their life's work. The study of the stock-killing and poisonous plants with the medical applications does this in a peculiar way. These two reasons are the ones which determined the placing of the technical laboratory methods first in the arrangement of the subject matter of this text-book. The study of the forage plants (grasses and legumes), of the weeds and of seed testing, which are presented in the final chapters of the book, is pursued naturally most satisfactorily, when the weather conditions permit the gathering of fresh material for lecture and laboratory purposes, and when to some extent outdoor work is made possible and pleasant. The teacher in the southern states, or on the Pacific slope, or elsewhere, where the climatic conditions of the winter months permit, can reverse the treatment of the subject by beginning the course with the contents of Chapter 10 and end the course with the perhaps less familiar and technical chapters (Chapters 1–9 inclusive). In fact this arrangement was suggested by a prominent teacher of agricultural botany, as the logical treatment of the subject matter of the text-book.

Where a text-book is considered advisable by the teacher for the work of the first term, the following books may be recommended for study in connection with the lectures and the laboratory work in general botany: *Allen, Charles E.* and *Gilbert, Edward M.*, Text-book of Botany. Boston, D. C. Heath & Co.; *Gager, C. Stuart:* Fundamentals of Botany. Philadelphia, P. Blakiston's Son & Co.; *Ganong, William F.:* A Text-book of Botany. New York, The MacMillan Company, 1918; *Martin, John N.:* Botany for Agricultural Students. New York, John Wiley and Sons, 1919; *Transeau, Edgar Nelson:* Science of Plant Life. Yonkers-on-the-Hudson, New York, 1919. For the laboratory course the writer uses *Harshberger, John W.:* Students' Herbarium for Descriptive and Geographic Purposes. Philadelphia, Christopher Sower & Co.

The chapters end with laboratory exercises and the methods of utilizing the illustrative material, which should accompany the detailed treatment of the subject. In order to appeal to a large number of teachers of agricultural botany, both in this country and abroad, the plants suggested for the laboratory exercises are selected from the common plants of the different countries and regions concerned. The good teacher, however, will be able to adapt the means to the end without slavishly depending upon the laboratory exercises, which with him will serve as suggestions of the line of work which he can undertake successfully in the allotted time. It is hoped, that the bibliographies at the ends of the chapters will prove helpful. The book, bulletins and papers mentioned in these bibliographies indicate the sources of the information in the text and in order to simplify printing such references are omitted as foot notes from the pages of the book. What material of the text, which is not mentioned specifically as derived from the author's own research and study, has been gleaned from a great variety of sources, such as personal interviews with farmers, agricultural professors and stockmen, or from books, bulletins and magazine articles, which have been read and the information contained therein has been absorbed and has become part of the mental equipment of the writer. Where the subject matter of the text has been taken from printed books and bulletins, it has been rewritten and recombined, so as to become a part of the warp and woof of the finished literary fabric herewith presented.

It is hoped, that this handbook will appeal to the student of plant life, particularly to the people, who, as agriculturalists, stock raisers and veterinarians, want to know something concerning the botany of the economic plants of interest to them in their agricultural, pastoral, or professional work. The plants chosen for treatment in the descriptive text, as the injurious, or useful, are those which have proven to be so. Plants of doubtful position in these respects have been omitted. The writer wishes to acknowledge the help of Dr. John A. Kolmer of the Medical School, of the University of Pennsylvania, who has read the pages on the phytotoxins and Ehrlich's theory of immunity; of Dr. C. Dwight Marsh, Expert, Poisonous Plant Investigations, Bureau of Plant Industry, U. S. Department of Agriculture for cooperation in securing the use of published departmental photographs and to Mr. C. V. Brownlow of the firm of P. Blakiston's Son & Co. for the encouragement, which he has given during the publication of the book.

JOHN W. HARSHBERGER.

Philadelphia, July 31, 1920.

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CHAPTER I

STOCK-KILLING PLANTS

The injurious plants of country and farm may be divided for convenience of treatment into those which cause physical injuries to animals and to man in a mechanical way and into those which cause injury, disease, or death by some deleterious, or poisonous substance possessed by the plant. The former have been termed stock-killing plants and the latter poisonous plants. There is no sharp demarcation between the two kinds of plants, but the distinction has proved to be a useful one.

The first group includes those plants which are mainly harmful to cattle, causing serious troubles, which may result eventually in the death of the animal. This group includes a considerable number of species none of very close taxonomic relationship. The anatomical and morphological peculiarities upon which the injury depends are very diveıse and consequently they become active in a great variety of ways.

Aspergillus fumigatus.—This grayish-green mould fungus was first discovered by Fresenius in the bronchial tubes and air cavities of the bustard. The fungal herbage on culture media is greenish turning to gray and even to dirty brown. It is readily identified by the short conidiophores (0.1–0.3 mm. long) with club-shaped extremity and simple upright sterigmata forming long chains of very small (2–3 μ), globular conidiospores. True perithecia are known with thin-skinned asci and light-red, lenticular, tough-skinned spores (4–4.5 μ) surrounded by a pale, radially striped, equatorial band. The fungus grows at a high optimum temperature (about 40°C.) and hence is well adapted to thrive in living animals at blood temperature.

Pathogenicity.—It causes pathogenic conditions in animals and man by growth in the lung tissue and in the air passages, where its presence causes difficulty of breathing and develops a toxin comparable to the toxins of the bacteria. Death may be caused by the filling of the air cavities which leads to the final asphyxiation of the host, as well, as to a generalized affection similar to hemorrhagic septicemia. It occurs in the human ear producing otomycosis, and in the bronchi (bronchomycosis), and in the lungs of birds, calves and man causing pneumomycosis. Pigeon-fatteners in Paris are men who feed thousands of young pigeons daily by filling their mouths with a mixture of grain and water, which they force into the mouths of the pigeons, much as the parent pigeons feed their young. These men suffer from aspergillosis, which is a pulmonary disorder resembling tuberculosis and occasionally fatal.

Cases.—The most remarkable case was the presence of the fungus in the lungs of a calf, which had died of a form of pneumonia. An autopsy by Dr. M. P. Ravenel in which the writer participated revealed the presence of lumps on the external surface of the calf's lungs. Celloidin sections of these pseudo-tubercular lesions mounted as double-stained microscopic preparations revealed the ramifications of the mycelium through the lung tissues and the emergence of the conidiophore with its mass of radiating spores extending into the cavities of the lungs from which by being coughed up in the sputum the conidiospores have been distributed. Some few lung spaces had three large fruit-bodies of the fungus present, almost completely filling the cavity.

Bromus tectorum.—The awned brome grass is a slender, erect annual with narrow pubescent leaves and nodding panicles of spikelets. The lemmas of each floret are rough and hairy terminating in awns at least 13–20 mm. long (½–¾ inch). The flowers appear from June to August and in Utah and Colorado during this period it has become a serious pest. Its injurious effects are due to the mechanical presence under the teeth of the awned glumes where they cause inflammation and suppuration, the animals which have eaten the grass frequently losing their teeth as a consequence.

Cenchrus tribuloides.—The sand bur is a grass common in sandy places and along railroads from Maine to Florida and in Texas, the Dakotas and California. The spikelets of this annual grass are surrounded by a spiny involucre which forms a hard, rigid bur with strong, barbed spines. The bur is readily detached from the plant and its spines enter the skin and flesh of animals, especially the lower part of the extremities, causing serious inflammation in man and the lower animals.

Heteropogon contortus.—A grass native of New Caledonia is one which bores into the skin and intestines of the lower animals causing fatal inflammation and peritonitis.

Hordeum jubatum.—The squirrel-tail grass, or wild barley, is found widely distributed in North America being an annual, or a winter annual. The flowers are arranged in a dense spike, each consisting of a number of 1-flowered spikelets, three occurring at each joint. The central spikelet has the perfect flower and produces one seed, while the lateral spikelets are reduced to awns and together with the subulate, rigid glumes and the awned lemma of the fertile flower simulate a bristly involucre at each joint of the rhachis. At maturity, the joints fall with the spikelets attached.

It has been recognized for some time that the barbed spikelets of this species of *Hordeum*, along with perhaps two other species, act injuriously in a mechanical way, causing deep ulcerations, or sores, of the tongue and lips of cattle and horses with the awns buried deeply in the tissues. They are frequently found between the teeth, where they cause suppuration of the gums and ulceration of the bones of the jaw.

Stipa capillata, S. comata, S. setigera, S. spartea.—The first species is indigenous to Russia; the second, known as needle grass, is distributed in western Iowa, Nebraska, Utah, Oregon, California and Arizona. The third species, known as porcupine grass, is widely distributed in western North America, while *S. setigera* is found in Uruguay and other South American countries. The species of *Stipa* are perennial grasses with 1-flowered spikelets with bristle-tipped glumes. The lemmas are hard, terminating in a twisted awn, and these lemmas tightly inclose the seed at maturity. This twisted awn is very hygroscopic, twisting up in dry weather, and untwisting, when the air is moist. When such an awn with its pointed, hard, sharp point below becomes entangled in the wool of sheep the pointed fruit by the gimlet-like motion of its spirally twisted, sometimes feathery awn bores into the skin and the flesh of the animal by the hygroscopic movements of the awn. The entrance of a large number of these barbs into the skin and underlying tissues produce an inflammation that is sometimes followed by the death of the animal. The Uruguayan species (*S. setigera*) injures the eyes of sheep, producing intense keratitis often followed by inflammation of the cornea and ultimate blindness, so that the sheep, thus injured, are unable to find their food and die of starvation and thirst.

Aegagropilæ and Phytobezoars.—These two words connote the same idea as that of hair balls. An aegagropila is a hair ball found in the stomach and intestines of some ruminants, as the goat αἴγαγρος, the wild goat + pila, a ball), formed by the goat, or other animal licking the hair off from the breast and forelimbs and swallowing it, so that in the stomach and intestines it is rolled into a large ball the size of the fist. These balls may cause the death of the animal in which they form by a stoppage of the bowels. The same word has been applied by extension of the idea to the balls of seaweed found on the Mediterranean Coasts. The Ligurian grass-wrack, *Posidonia oceanica*, is found in the bay between the old town of Antibes and the projecting Cap in such great quantities that the shore is heaped high with its torn off leaves. To the west of the Cap, on the sands of the Golfe Jouan, round balls of a light brown color and fibrous structure are often found. These used to be seen in chemists' shops under the name of "pilæ marinæ." They are loose pieces of the rootstock of Posidonia covered with the frayed remains of leaves. These are tossed about on the beach by the waves until they are formed into balls (aegagropilæ, phytobezoars), a decimetre in circumference. A bezoar (or where caused by plant materials, a phytobezoar) is a concretion found in the digestive tract of ruminants and formerly supposed to be efficacious in preventing the fatal effects of poisons and still held in repute in eastern countries, hence the derivation of the word from the Persian *Padzahr* (pad, expelling + zahr, poison) becoming in Arabic badizahr, bazahr and in new Latin bezoar.

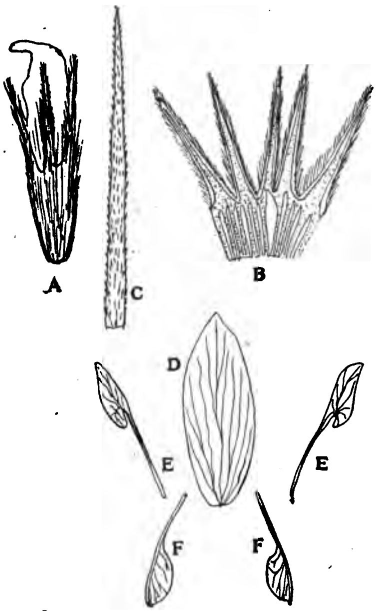


Fig. 1.—Details of the flower of the crimson clover (*Trifolium incarnatum*). *A*, Hairy calyx with withered corolla; *B*, calyx opened out; *C*, one of the shorter hairs of the calyx; *D*, standard; *E*, wing petals; *F*, keel petals.

Clover Hair Balls.—Since 1895, when Dr. F. V. Coville described the result of cattle eating the crimson clover, *Trifolium incarnatum*, when in the flowering condition, a large number of cases of the death of animals by the formation of crimson clover phytobezoars have been reported. The earlier evidence recorded by Coville in his bulletin is given herewith. Mr. William P. Corsa forwarded to the Department of Agriculture a ball of peculiar appearance, stating that it had been taken from the stomach of the horse belonging to Joseph W. Messick of Milford, Del., which had been eating crimson clover, and the death of which was ascribed to the ball formed from the branched hairs and fibers of the calyces of the crimson clover flowers (Fig. 1). Another man, Mr. Alexander Ryan, a few days before the above report had been filed, had lost a horse from which two similar balls had been taken. Later another letter from an entirely

FIG. 2.—Crimson-clover hair balls taken from horses which had died from the presence of these masses in the alimentary tracts. The larger one is the largest of six taken from a horse which had been fed on crimson-clover hay for 12 years before his death. Horses have died within a few months after commencing to eat crimson clover. The smaller hair ball is as large as a regulation baseball. (*After Westgate, J. M.: Crimson clover: Utilization. Farmers' Bulletin*, 579, 1914, *p*. 6.)

different locality, Kellar, Va., was received by the Department written by B. W. Mears & Son accompanied by a ball taken from the horse immediately after death. The statement was made that the horse had worked as usual without any signs of disease up to the time of its fatal illness which lasted five hours with sharp pain before death. Another ball, similar to that taken from the stomach, was found in the large intestine. Several other horses in the vicinity had died the preceding week, all apparently from the same cause, and the farmers had ascribed it to the feeding of crimson clover. Another case was reported in the summer of 1895 by Dr. Charles F. Dawson of Washington, who received from a veterinary surgeon of Raleigh, N. C., three balls which he had removed from the intestine of a horse after death. The personal acquaintance of the writer with crimson clover phytobezoars happened some years later when his attention was called to the death of six horses near Westville, N. J. with the receipt of two large balls sent as museum specimens by a former student, a practicing veterinarian. A ball in the possession of the writer taken from a horse at Oxford, Penna, is about the size of a fist. Coville states that they are nearly spheric and measure from three to four and one-half inches in diameter. The stiff, bristly calyx hairs are matted together and are cemented to some extent by the mucus derived from the digestive tract of the animal in which they form (Fig. 2).

Cactus Spine Balls.—Prof. William Trelease reported in 1897 a still more interesting phytobezoar. "In January, 1897, Dr. Francis Eschanzier of San Luis Potosi, Mexico, sent to me two specimens, one a ball of surprising accuracy of surface, measuring a little over three and one-half inches in diameter, and weighing seven and one-half ounces, and the other, one-half of a similar ball, about four inches in diameter, and weighing about four ounces, stating that sixteen such balls had been taken from the stomach of a bull at the Hacienda de Cruzes, and adding that he believed them to be composed entirely of an agglomeration of the fibres of some cacti, an undigested portion of which formed the nucleus."[1] Inspection of the balls by Prof. Trelease proved this supposition to have been the correct one. The specimens were of a brown color, and consisted of the barbed hairs with which the mamillæ of the *Platopuntias* are armed. In the West and Southwest, where one of the opuntias with long spines is fed to cattle (*Opuntia Engelmanni*), it is customary to remove the long spines by the use of fire, but this does not entirely remove the danger of their use. The late Dr. Vasey of the U. S. Department of Agriculture gives a number of instances in which cattle have died from an accumulation of spines in the mouth and stomach.

Leaf Hairs of Plane Trees.—Dioscorides and Galen, two early Greek physicians, called attention to the injurious effects of the hairs found on newly expanded leaves of plane trees (*Platanus*) and on the surface of the ball-like clusters of pistillate flowers. These hairs, which fall off in great numbers, in the spring of the year, if inhaled, produce inflammation of the nose and throat. Severe coughs are the result of the inhalation and accumulation of the star-like hairs in the respiratory passages. See Gardeners' Chronicle 3d. Ser. III, 370, March 24, 1888.

Bibliography

Britton, N. L. and Brown, Addison: An Illustrated Flora of the Northern United States, Canada and the British Possessions, second edition, volumes I and II. Genera *Bromus*, *Cenchrus*, *Hordeum*, *Stipa*, *Trifolium*.

Coville, F. V.: Crimson Clover Hair-balls, Circular No. 8, Div. of Botany, U. S. Department of Agriculture, June 15, 1895.

Harshberger, John W.: A Review of Our Knowledge of Phytobezoars. The Journal of Comparative Medicine and Veterinary Archives, xix, 143, March, 1898.

Kerner von Marilaun, Anton and Oliver, F. W.: The Natural History of Plants. Half Volume II, 616–620.

Pammel, L. H.: A Manual of Poisonous Plants. Part II, 1911, pages 262–266; 336–369.

Pearson, Leonard and Ravenel, M. P.: A Case of Pneumonomycosis Due to Aspergillus Fumigatus. University Medical Magazine, August, 1900.

Robinson, B. L. and Fernald, M. L.: A Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada. (Gray's New Manual of Botany, 7th edit., 1908.) Same genera as in Britton and Brown.

Strasburger, Edward: Rambles on the Riviera. English translation by O. and B. C. Casey, 1906, 411–412.

Trelease, William: Cactus Hair Balls. Transactions of the Academy of Science of St. Louis, vii, 493, Nov. 30, 1897.

Laboratory Work

Suggestions to Teachers.—Cultures of *Aspergillus fumigatus* should be kept on nutrient agars in test tubes as stock material. Fresh transfers of this fungus should be made at least once every two months throughout the year. Such stock material, allowing sufficient time for new growth to take place after inoculation of fresh agar, can be kept conveniently in the ice box, or refrigerating plant, of the laboratory. When the culture is used for laboratory study by the class, transfers should be made to slices of wet bread fitted into Petri dishes and sterilized in the autoclave before use. *Aspergillus fumigatus* makes a rapid growth on the surface of the bread and is removed easily for examination by the members of the botanical class.

Dried specimens of the injurious higher plants should be kept between folded newspapers, having been collected for the purpose during the growing and flowering season. Some of the material at the discretion of the teacher can be preserved in alcohol, or formalin. A number of hair balls should be kept on hand for the lecture table and for detailed study by the class.

Laboratory Exercises

1. Remove some of the mycelium with the conidiophores of *Aspergillus fumigatus* from the surface of the bread in the Petri dishes with a pair of smooth forceps. Place on a slide in 50 per cent. alcohol, so as to wet the hyphæ. Drain off the alcohol and mount in acetic acid (2 per cent.), applying a ring of asphaltum. Study and draw.

2. Study and draw the awned brome grass, *Bromus tectorum*, and dissect out the parts which collectively become injurious to animals.

3. Do the same for the sand bur, *Cenchrus tribuloides*, and the squirrel grass, *Hordeum jubatum*.

4. Compare the three, or four, species of feather grass, *Stipa capillata*, *S. comata*, *S. spartea* and make detailed drawings of the spikelets with attached spirally twisted awns.

5. Macerate portions of the crimson clover hair balls in potassium hydroxide dissolved in water in a porcelain evaporating dish over the Bunsen burner flame. Compare the parts thus released with the hairs on the calyces of crimson clover flowers preserved in alcohol. Draw the material from the two sources for comparison.

6. Remove the hairs from the leaves of plane trees and study under the microscope. A supply of the leaves for this purpose should be gathered in the spring. Young leaves of plane trees should be preserved in alcohol for later class study.

CHAPTER 2

POISONING BY PLANTS. GENERAL PRINCIPLES

Poisonous plants are those which contain some deleterious or toxic substance, which injures health, causes intoxication,[1] lowers the physical and mental tone, produces at times convulsions and in many cases results in the death of the victim.

The classification of poisons has been attempted by a number of toxicologists. While their classifications are a scientific attempt at arranging the facts known about poisonous substances, they are only approximations. Much remains to be done along the lines opened up by modern chemistry, physiology and toxicology. Blyth gave one of the earlier and simpler of the classifications proposed for poisons.

Blyth's Classification of Poisons.

A. Poisons causing death immediately, or in a few minutes.
   Prussic acid, strychnin.

B. Irritant Poisons. Symptoms mainly pain, vomiting and purging.
   Savin, ergot, digitalis, colchicum, yew, laburnum.

C. Narcotic and Irritant Poisons. Symptoms of an irritant nature, with more or less cerebral indications.
   Oxalic acid, or oxalates.

D. Poison more especially affecting the nervous system.
   1. Narcotics. Chief Symptoms: insensibility which may be preceded by more or less cerebral excitement. Opium.
   2. Deliriants. With delirium as a prominent symptom: Belladonna, hyoscyamus, stramonium and other Solanaceæ, poisonous fungi, Indian hemp, darnel, etc.
   3. Convulsives. Alkaloids of the strychnin class.
   4. Nervous phenomena of complex character. Aconite, digitalis, poison hemlock, curare.

Kobert's Classification of Poisons.—The writer has used this classification of Kobert for a number of years in his exposition of the subject of poisonous plants at the University of Pennsylvania. It is a useful one in emphasizing the organs of the animal affected by poisons.

[1] Not used in sense of drunkenness, as after an alcoholic debauch.

I. Poisons which Cause Gross Anatomic Changes of the Organs.
  A. Those which act as irritants.
    1. Acids; (2) Caustic alkalis; (3) Caustic salts; (4) Locally irritating substances such as cotton oil and savin; (5) Gases and vapors which cause local irritation when breathed, as chlorine.
  B. Those with little local effect, but alter other parts of the anatomic structure, as lead and phosphorus.

II. Blood Poisons.
  1. Those which interefere in physical manner with the circulation, as: ricin, abrin.
  2. Poisons which have the property of dissolving the red corpuscles, as saponin.
  3. Poisons which with or without solution of the red corpuscles produce methæmoglobin, as picric acid.
  4. Poisons which have a peculiar action on the coloring matter of the blood, or on its products of decomposition, such as carbon monoxide.

III. Poisons which Kill without Anatomic Change.
  1. Cerebro-spinal poisons, as cocaine, atropin, morphin, nicotin, coniin, aconitin, strychnin, etc.
  2. Heart poisons, as digitalis, helleborin, muscarin.

IV. Poisonous Product of Tissue Change.
  1. Poisonous albumin.
  2. Poisons formed in foods.
  3. Auto-poisoning, as uræmia.
  4. Products of tissue change, as ptomaines, etc.

Bernhard H. Smith's Classification of Poisons.—This is one of the most complete classifications proposed, and is adopted by L. H. Pammel in his Manual of Poisonous Plants (1910).

The main facts of this classification without going into a consideration of the treatment which Pammel gives in his outline are as follows:

Poisons Acting on the Brain

I. Narcotics.

Symptoms.—Giddiness; dimness of sight; contracted pupils; headache; noises in the ears; confusion of ideas, and drowsiness, passing into insensibility.

Example.—Poppy (*Papaver somniferum*).

II. Deliriants.

Symptoms.—Special illusions; delirium; diluted pupils; thirst and dryness of the mouth; occasionally, though rarely, paralysis and tetanoid spasms.

Examples.—Thorn Apple (*Datura Stramonium*). Black Nightshade (*Solanum nigrum*), Hemp (*Cannabis sativa*), Darnel (*Lolium temulentum*) and Fly Agaria (*Amanita muscaria*).

III. Inebriants.

Symptoms.—Excitement of cerebral functions, and of the circulation; loss of power of co-ordination, and of muscular movements, with double vision; leading to profound sleep, and deep coma.

Examples.—Wormwood (*Artemisia Absinthium*), Jamaica Dogwood (*Piscidia Erythrina*).

Poisons Acting on the Spinal Cord

Convulsives.

Symptoms.—Clonic (intermittent) spasms, extending from above downwards. Opisthonas very violent; but trismus (lock-jaw) rare. Swallowing spasmodic. Death, usually, in less than three hours, or rapid recovery.

Examples.—Nux vomica (*Strychnos Nux-vomica*), St. Ignatius's Bean (*Strychnos Ignatii*).

Poisons Acting on the Heart

I. Depressants.

Symptoms.—Vertigo; vomiting; abdominal pain; confused vision; convulsions; occasional delirium; paralysis; syncope; sometimes asphyxia.

Examples.—Tobacco (*Nicotiana Tabacum*), Hemlock (*Conium maculatum*), Indian Tobacco (*Lobelia inflata*).

II. Asthenics.

Symptoms.—Numbness, and tingling in the mouth; abdominal pain; vertigo; vomiting; purging; tremor; occasional delirium; paralysis; dyspnoea, ending in syncope.

Examples.—Aconite (*Aconitum Napellus*), Cohosh (*Cimicifuga racemosa*), Oleander (*Nerium oleander*), Foxglove (*Digitalis purpurea*), White Hellebore (*Veratrum album*), Green Hellebore (*Veratrum viride*).

Vegetable Irritants

I. Purgatives.

Symptoms.—Abdominal pain; vomiting, and purging, cramps strangury and tenesmus, followed by collapse, and sometimes accompanied by drowsiness, and slight nervous symptoms.

Examples.—Castor Bean (*Ricinus communis*), Green Hellebore (*Helleborus viridis*), May Apple (*Podophyllum peltatum*), Marsh Marigold (*Caltha palustris*).

II. Abortives.

Symptoms.—Nausea; vomiting; stupor; sometimes tenesmus; abortion may or may not occur; coma.

Example.—Ergot (*Claviceps purpurea*).

III. Irritants with Nervous Symptoms.

Symptoms.—Abdominal pain; vomiting and purging; dilated pupils; headache; tetanic spasms; occasional covulsions; sometimes rapid coma.

Examples.—Indian Pink (*Spigelia marilandica*) Fool's Parsley (*Aethusa Cynapium*).

IV. Simple Irritants.

Symptoms.—Burning pain in the throat and stomach; thirst; nausea; vomiting; tenesmus; purging; dysuria; dyspnoea and cough occasionally, death through shock; convulsions; exhaustion; or starvation due to throat or stomach.

Examples.—Bouncing Bet (*Saponaria officinalis*), Poison Ivy (*Rhus Toxicodendron*), Kinnikinnik (*Arctostophylos Uva-ursi*).

V. Simple Irritants when Taken in Large Quantities.

Symptoms.—Burning pain in throat and stomach. Vomiting; purging; difficulty in swallowing. Recovery usual.

Examples.—White Mustard (*Brassica alba*), Black Mustard (*B. nigra*), Black Pepper (*Piper nigrum*), Common Ginger (*Zingiber officinalis*).

Conditions Influencing the Formation of Plant Poisons.—The commercial study of drug plants in which the substances used as drugs are poisonous to animals in uncontrolled doses has shown that the amount of poison found in the plant and its activity varies considerably. It has been found by a comparative study of the drug content of such plants and also by experimental investigation, that there are various conditions which influence this variation. The following are some of the reasons for this difference in the amount and activity of the poison derived from the same species of plant.

1. **Glucoside Transformation.**—It has been found that in some plants the poisonous substance does not exist in the plants themselves, but appears only when one substance in the plant comes in contact with and is acted upon by another substance which may be called the activator. This is illustrated in the leaves of the wild black cherry, *Prunus serotina*, which do not contain any active poison until they become dried, when its glucoside substance, probably amygdalin, is acted upon by emulsin, an enzyme, and converted into the poisonous hydrocyanic, or prussic acid.

2. **Influence of Age of Plant.**—The age of the plant materially influences the virulence and the amount of poison present in the plant. Sometimes a young plant is more actively poisonous than an old plant and vice versa. The death camas, *Zygadenus venenosus*, native of Montana and other western states is more poisonous before it comes into bloom. On the other hand, the seeds of the lupines (*Lupinus*) are the only parts of the plants positively known to be poisonous.

3. **Character of Organ.**—Different organs of the same plant vary as to their content of poison. Some parts are inert, others are deleterious. The green leaves and stems of the common potato, *Solanum tuberosum*, are poisonous, especially when wilted, while the tubers form an everyday article of diet. The fruits of spotted cowbane, *Conium maculatum* and the seeds of *Datura Stramonium*, the thorn apple, are more poisonous than the foliage.

4. **Seasonal Variation Poisons.**—There is a considerable variation in the amount of poisonous material produced in plants from season to season. Thus the mature bulbs of *Colchicum* contain a much larger amount of toxic substance than the growing bulbs. Miss Alice Henkel in a paper on "American Root Drugs" notes that the roots of the American hellebore, *Veratrum viride*, should be collected in the autumn after the leaves are dead.

5. **Influence of Climate.**—Climate has a marked influence on the development of poisonous substances in plants. Dunstan has shown (Bul. Imp. Inst. 1905) that *Hyoscyamus muticus* grown in India yielded 0.3 to 0.4 per cent. of hyoscyamin, but that the same species grown in Egypt produced 0.6 to 1.2 per cent. Esser states that no coniin is found in the spotted cowbane, *Conium maculatum*, in the far north.

6. Influence of Soil.—The soil has considerable influence on the amount of poisonous substance developed in plants. The trailing, yellowish-green form of poison ivy, *Rhus radicans*, found on the coastal sand dunes is less virulent than the climbing form found inland. This difference in the poisonous properties is to be attributed to growth on the barren sand of the sea coast.

7. Influence of Cultivation.—Cultivation has a marked influence. In general, wild poisonous plants have larger amounts of alkaloids and glucosides than the same species when cultivated, although this does not always hold true. The wild forms of the Lima bean, *Phaseolus lunatus*, contains much more HCN than the cultivated forms.

8. Variation in Amount of Poison.—The amount of poison contained in plants of the same species depend upon the race or variety of that particular species utilized for the extraction of the drug, or poison. Blyth records the following percentages of nicotin in various tobaccos as given by Cox (Pharm. Journ., Jan. 20, 1894). Syrian leaves (*a*) .612 per cent.; Syrian leaves (*b*) 1.093 per cent.; Gold Flake (Virginia) 2.501 per cent.; Navy Cut (light colored) 3.640 per cent.; Best Shag (*b*) 5.000 per cent.: Algerian tobacco (*a*) 8.813 per cent.

9. Weather and Poisoning.—The state of the weather has considerable effect on the number of cases of poisoning among cattle on the free range. The death camas, *Zygadenus venenosus*, found in California, is a case in point. The bulbs of this plant are dangerous only after rains, since at other times, it is almost impossible for sheep to pull them out of the ground. Many serious cases of stock poisoning have occurred after late spring and early autumn snow storms, because the grasses and other low plants are covered with snow and only the taller plants remained visible and then were poisonous.

10. Seasonal Distribution of Cases of Poisoning.—There are more cases of poisoning of stock in certain seasons of the year than others. Laurel, *Kalmia latifolia*, is more likely to be browsed in winter and early spring, because of its attractive, bright green color, when other plants are dormant. Cattle are more subject to loco disease in the spring, because the loco weeds become green early in the spring and are browsed upon by animals while the other green herbage is scarce at this time of the year.

11. Specific Differences of Animal Susceptibility.—The different kinds of live stock are affected quite differently by poisonous plants. Human beings are most susceptible to the deadly night shade, *Atropa Belladonna.* The cat and dog are less susceptible. The horse is much less so, and the pig, goat, sheep and rabbit are little susceptible to poisoning, even on eating the root, the most poisonous part.

12. **Individual Susceptibility.**—There is a difference in the individual susceptibility to poisons. The best illustration of this is the case of poison ivy producing the characteristic inflammation on fair persons with blue eyes (blondes), and the immunity of persons with dark, swarthy complexions (brunettes). This individual difference varies with the health of the animal, or man. The healthy individual having greater immunity than the one in a depleted condition. Animals familiar with certain ranges escape poisoning, while those not so familiar may be poisoned.

13. **Physical State of Animal.**—The physical state of the animal, whether hungry, or well-fed, whether kept in confinement, or allowed the freedom of the open fields influences the number of cases of poisoning. When animals are hungry; or are turned out into the open fields after confinement, they are more likely to eat of poisonous plants than otherwise. This has been shown recently in the case of laurel poisoning of heifers at Narberth, Pennsylvania.

14. **Animals with Depraved Appetite.**—The animal may acquire a depraved appetite where it leaves off feeding on the nutritious pasture plants and takes to eating the deleterious ones. This happens with the loco weeds; when the depraved appetite of the animals leads them to eat only the plants which have induced the loco disease.

15. **Unpalatable Poisonous Plants.**—Poisonous plants are frequently unpalatable and so are not usually eaten, but in dry spells, when other forage is scarce, they may be eaten with poisonous results.

16. **Secondary Fermentations in Fodders.**—Perfectly wholesome fodders may become poisonous owing to secondary fermentations within them, as occurs sometimes in maize silage.

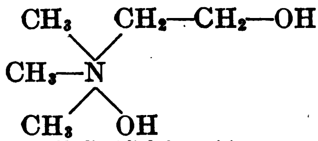
17. **Poisonous Plants as Impurities.**—A perfectly harmless feed may become poisonous owing to the admixture of a poisonous plant, or plant part with it, as oats with corn cockle and barley with darnel. In Europe dry meadow-saffron may be included in hay.

18. **Removal of Animals to New Locality.**—Farm stock reared in a locality where certain poisonous plants abound are much less likely to be poisoned by these plants than animals brought from a region where they do not occur.

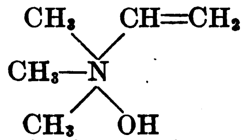
Chemical Nature of Poisoning

The modern chemical investigation of poisonous plants has resulted in the isolation of the active principles of many plants which have been determined to be nitrogenous substances of basic character, and to this class of substance the name of alkaloid has been given. It has been found also that all poisonous plants do not contain alkaloids, but in addition there are non-alkaloidal active principles, which include a large number of different types of chemical compounds, including the substances known as glucosides, which are readily hydrolyzed by dilute acids, or by ferments into a sugar and another constituent, which is generally physiologically active. The isolation of the active compounds has been of importance in determining the strength of the dosage of the drug, which could be safely administered to animals. The study of these actively poisonous substances led to various attempts at their production synthetically. Chemists owing to the backward condition of their science were unable to produce the complex active substances, but their study has led to the discovery of the portion of the molecule which produces the physiological effect and this has led to the discovery of simpler analogous compounds possessing the action of the drug, or poison.

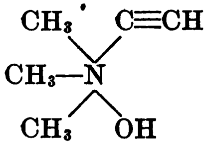
The discovery was made that the physiological action of the drug, or poison, was dependent in general on its chemical nature, although modified naturally by differences in physical properties such as solubility, volatility and the like. Thus, a very small change in the chemical constitution of a poison, is often accompanied by a complete change in its physiological action. There is often a great difference in the activity of stereo-isomerides. In the case of optically active stereo-isomerides, we find marked differences in their physiological action. For example, atropin (racemic hyoscyamin) differs in some respects from *lævo*-hyoscyamin, and *lævo*-nicotin is twice as actively poisonous as the *dextro*-variety. Adrenalin is a striking example, the natural *lævo* form being about eleven, or twelve times as active as the *dextro*. *Dextro*-asparagin is sweet. *Lævo*-asparagin is tasteless. Unsaturated compounds are usually far more toxic than the corresponding saturated ones. Propyl alcohol, $CH_2-CH_2-CH_2-OH$, is a narcotic, causing intoxication, although not really poisonous, whereas allyl alcohol, $CH_2=CH-CH_2-OH$, is a strong poison, although not having narcotic action. The influence of increasing unsaturation is displayed in the graphic formulæ below: from May's "The Chemistry of Synthetic Drugs," page 32.



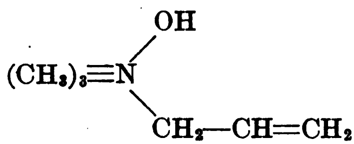
Cholin (slightly toxic)



Neurin (very toxic)

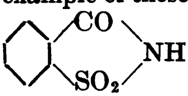


Far more toxic than neurin



A homologue of neurin only slightly poisonous

The study of the physiologic action of ortho, meta, and para compounds has shown differences, such as that the para compounds are more poisonous than the ortho, although occasionally the reverse is the case. An example of these differences may be cited. Saccharin, an orthocompound,



is five hundred times sweeter than sugar, while the corresponding para compound is without taste.

The Organism and The Poisonous Substance

Hydrolytic cleavages in the alimentary canal, more profound oxidation changes and sometimes reduction in the blood or tissues are chemical processes taking place in the organism. The saliva acts on few drugs, but in the stomach many drugs can be absorbed and where unpleasant by-effects are often manifested. This has led to the synthesis of new drugs which are not absorbed in the stomach. When the substances enter the intestine, they enter an alkaline medium and are acted upon by the pancreatic enzyme, trypsin, which hydrolyzes esters, anilides and similar bodies. The drugs are able to exert their specific action after saponification in the intestine and the pharmacologist recognizing this fact prepares derivatives the components of which would cause unpleasant effects on the stomach, but for the fact, that they are not decomposed in that organ, but are hydrolyzed in the intestine, where they can exert the desired result.

The aliphatic hydrocarbons have narcotic properties, and these are increased by the introduction of an hydroxyl group to form alcohols. If more hydroxyl groups are introduced, as in glycerol, the narcotic action disappears, the hydroxyl merely playing the rôle of an "anchoring" group. The narcotic action of many substances on the other hand is associated with the presence of alkyl groups, especially ethyl groups. The alkyl group is the active portion of the molecule in the alcohols, and not the hydroxyl group. If halogen and especially chlorine replaces the hydrogen atoms in a hydrocarbon, the narcotic action is greatly increased. The presence of an ethyl group in a considerable number of compounds, gives to the substance the power of connecting with the nervous system. An excessively large dose of ethyl alcohol produces sleep, but a number of compounds with ethyl groups have been discovered which have a hypnotic action in smaller doses.

Alkaloids.—The alkaloids are not widely distributed in the vegetable kingdom. They are classified usually into five groups, as follows: (1) Pyridin Alkaloids, such as coniin from *Conium maculatum*, nicotin from *Nicotina tabacum*. (2) Pyrrolidin, Alkaloids. (3) Tropan Alkaloids, such as atropin from *Atropa Belladonna*. (4) Quinolin Alkaloids, as strychnin from *Strychnos Nux-vomica*. (5) Isoquinolin Alkaloids, as morphin. Four elements carbon, hydrogen, nitrogen and oxygen enter into the formation of the alkaloid. A few contain no oxygen. Most are colorless crystalline solids, a few being liquid. Most are insoluble in water, but dissolve in ether, alcohol, chloroform. They have a bitter taste and have strong physiological, or toxic properties, even in small doses, and a slight alteration in molecular structure often produces a decided change in their physiological and toxic properties. For example, the reduction of the nitrogenous ring generally produces a marked increase in the toxicity and strength of the action of the poison and sometimes alters its character. Pyridin is non toxic and lowers blood pressure, but piperidin is very toxic and raises blood pressure. The size and position of the side chains attached to the ring have an important effect. Pyridin can by reduction yield more active substance by the entrance of aliphatic chains which is accompanied by the appearance of intoxicating action. The toxic action of piperidin itself, which is not very strong, is increased in a methyl piperidin and still more in a methyl piperidin and a-propyl-piperidin (coniin). The toxicity of these substances is in the ratio of 1 : 2 : 4 : 8.

Ptomaines.—The bacteria and certain fleshy fungi have associated with their activities a number of basic substances with simple constitution, such as methylamine $CH_3\ NH_2$; dimethylamine, $(CH_3)_2\ NH$; trimethylamine, $(CH_3)_3\ N$; putrescin, $NH_2\ (CH_2)_4\ NH_2$; cadaverin, $NH_2\ (CH_2)_5$

NH_2, and cholin, muscarin, neurin which are much more complex. These substances are formed in decomposing flesh. Cholin and muscarin are found in the toad-stool, *Amanita muscaria.* Muscarin and neurin are both very poisonous, whereas cholin is slightly toxic.

Cholin is found in the seeds and fruits of *Pinus cembra,* nut of *Areca-catechu,* endosperm of coconut (*Cocos nucifera*) root of sweet flag *Acorus-calamus,* hop *Humulus lupulus.* Betain another member of the group occurs in the juice of the beet and in the tuber of *Helianthus tuberosus.* All these substances are strong bases and answer the general reactions for alkaloids. Immune substances are not produced for these chemical poisons as for the phytotoxins later described.

Glucosides. These are chemical substances of considerable complexity and yield glucose on decomposition with one or more other compounds, usually of an aromatic nature. The reaction is mostly hydrolysis. For example, amygdalin is hydrolyzed by emulsin, an enzyme, to glucose, benzaldehyde and prussic acid.

$$C_{20} H_{27}, NO_{11} + 2H_2O = 2C_6H_{12}O_6 + C_6H_5CHO + HCN.$$

This reaction expresses that of the cyanogenetic glucosides or those which on hydrolysis yield hydrocyanic, or prussic acid, a deadly poison.

Loew from the chemical standpoint states that all substances which are capable of acting on aldehyde or amino groups, even when in dilute solution, must be poisonous for living tissue on which they will exert a substituting action. The greater the reactivity of a substance for aldehyde (CHO) or amino (NH_2) groups, the greater will be its physiologic effect and its toxicity.

Vegetable Toxins (Phytotoxins).—The production of substances possessing the essential features of the toxins is not limited entirely to the bacterial cell. They are found in the flowering plants and are called phytotoxins. The chief phytotoxins are abrin from the Job's tear plant *Abrus precatorius;* crotin from the seeds of *Croton tiglium;* ricin from the castor-oil bean, *Ricinus communis;* robin from the leaves and bark of the black locust, *Robinia pseudacacia;* phallin from the toad-stool *Amanita phalloides,* and the toxin causing hay-fever found in pollen grains. These substances are very similar, resembling proteins in many respects, for they can be salted out of solutions in definite portions of the precipitate, are precipitated by alcohol and are slowly destroyed by proteolytic enzymes. Recent work by Harris, Mendel and Osborne has shown that the toxic properties of ricin are associated inseparably with the coagulable albumin of the castor beans, and were able to isolate this toxalbumin in such purity that one one-thousandth of a milligram (0.000001 gram) was fatal per kilo of rabbit and solutions of 0.001 per cent would agglutinate red corpuscles. The phytotoxins have been used extensively in the investigation of immunity, since they obey the same laws as bacterial toxins. They seem to possess haptophore and toxophore groups and immunity is readily obtained against them. The immunity is specific, ricin antitoxin, for example not protecting against abrin.

Their poisonous action is manifested in agglutination of the erythrocytes, local cellular destruction, and in hemolysis. Such toxalbumins as crotin and phallin are actively hemolytic, that is the hemoglobin escapes from the stroma of the blood corpuscles into the surrounding fluid. Ricin, abrin and robin are more marked by their agglutinating action, hemolysis being produced only by relatively large doses. They resemble the bacterial toxins, in that immunity can be secured against them, and the immune serum will prevent their hemolytic action. The hemolytic, or agglutinating, action of these toxalbumins, except phallin, is not destroyed by exposure to 65° to 70°C. of heat, but 100°C does destroy it. The action of these substances is not like that of the enzymes in being quantitative, a given amount acting on a given amount of corpuscles to which it is bound.

Another quite distinct group of vegetable hemolyzing agents are the saponin substances closely related to the glucosides and found as strong protoplasmic as well as hemolytic poisons. They differ from the true toxins in being resistant to heat, having no resemblance to proteins and do not give rise to antibodies on immunization of animals. The degree of their toxicity is not directly proportional to their hemolytic activity for they seem to chiefly injure the nerve-cells. Apparently hemolysis is brought about by action on the lipoids of the red corpuscles, for addition of cholesterol to saponin prevents its hemolytic effect. Kobert has shown that all cause hemolysis, some in dilutions as great as 1 : 100,000. The following are the most important members of this group: sapotoxin obtained from *Quillaja*, cyclamin from *Cyclamen*, solanin from members of the potato family, helvellic acid from fungus *Helvella esculenta*, phallin from toadstool, *Amanita phalloides*.

Applicability of Ehrlich's Theories.—As the theory of Ehrlich is applicable in the study of the activity of such toxins and the immunization of animals, a brief statement of Ehrlich's views is given here. Ehrlich reasoned that if it is by the chemical side chains of the organic molecules that change in the chemical composition of toxic bodies is brought about then the living cell has side-arms or receptors of the cell molecule by which the haptophore (binding portion of the toxin molecule) fits "like a key fits a lock." Each molecule of the animal cell has innumerable receptors of which only a certain number are suitable for the anchoring of the toxin molecule to the living cell. If only a few toxin molecules are united with the cell receptors then the toxin is of low toxicity and the effects on the cell will be slight, if more are anchored, the poisonous effects will be greater or entirely destructive to the cell. Regeneration of the receptors takes place, and if these are produced in such numbers by the activity of the antigen, or poison, they are crowded off and find their way into the blood serum, where they are capable of anchoring the toxin molecules as before and thus become the antibodies, or antitoxins, which finally bring about a neutralization of the toxin. The persistence of these antibodies (antitoxins) in the animal system produces immunization. We may summarize Ehrlich's conception of the nature of toxins, as follows: Each molecule of toxin consists of a great number of organic complexes grouped as in organic compounds generally as side chains about a central radical, or ring. One or more of these complexes has a chemical affinity for certain chemical constituents of the tissues of animals susceptible to the toxin with which the toxin molecule reunites. The toxin molecule must contain two separate atom groups. One of these must possess the power of binding and be stable. This is the haptophore, or anchoring group. The other one by which the toxin molecule exerts its deleterious action, must be more easily changed or destroyed. This is the toxophore, or poison group. An animal is susceptible to a toxin only when its cells contain receptive substances which possess a chemical affinity for the haptophore of the toxin molecule and also substances which can be influenced harmfully by the toxophore of the same molecule. The nature of the changes brought about by the toxophore of the toxin molecule is not understood, but there are many resemblances to the action of enyzmes or ferments, but the analogy is not complete. We find the closest analogy to the enzymes in the toxic substances that destroy the bacteria and the red-blood corpuscles (*bacteriolysins* and *hemolysins*).

The immunity against enzymes and toxic bodies seems to have an identical origin in the over production of the cellular receptors which bind the haptophore groups to the cells. These excessive receptors find their way into the blood where they combine with the enzyme, or toxin, so that it cannot enter into combination with the cells. To emphasize this point, the receptors eliminated by toxin absorption are not, therefore, simply reproduced in the same quantity in which they are lost, but are reproduced in excess of the simple physiological needs of the cell. Continuous and increasing dosage with the poison, consequently, soon

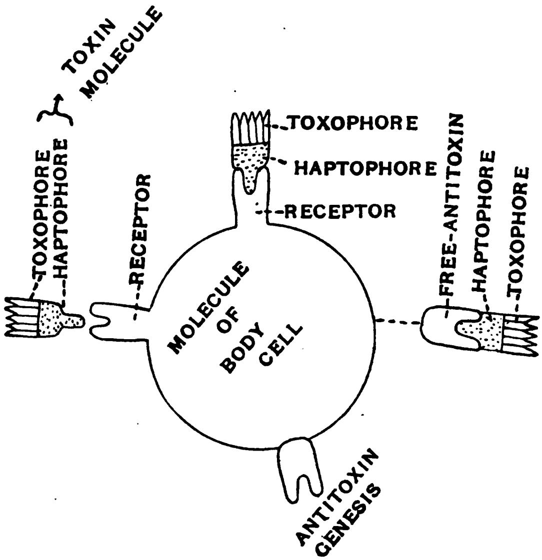


FIG. 3.—Diagram showing body cell molecule, cell receptors with linkage for toxin molecule with a binding group (haptophore) and a toxic group (toxophore). The receptors produced in excess by the stimulation of the body cell become the antitoxin molecules which are set free into the blood and then unite, as shown in the diagram, with the toxin molecules by means of their haptophores. The free antitoxin molecules thus unite with the poison molecules in the blood and thus protect the body cells.

leads to such excessive production of the particular receptive atom-groups that the cells involved in the process become overstocked and cast them off to circulate freely in the blood. These freely circulating receptor atom groups with specific affinity for the toxins used in their production represent the antitoxins. These, by uniting with the poison before it can reach the sensitive cells, prevent its deleterious action (Fig. 3). The theory of Ehrlich, in brief, then, depends upon the assumptions that toxin and antitoxin enter into chemical union, that each toxin possesses a specific atom group by means of which it is bound to a preexisting side chain of the affected cell, and that these side chains, under the influence of repeated toxin stimulation, are overproduced eventually and cast off by the cell into the circulation where they act as the antitoxin.

The phytotoxins act directly with erythrocytes in a manner like saponin. They do not require the presence of amboceptors and complements as in serum hemolysis, but produce hemolysis directly.

Bibliography

GREENE, CHARLES W.: Experimental Pharmacology. A Laboratory Guide. P. Blakiston's Son & Co., Philadelphia, 1909.

HAAS, PAUL and HILL, T. G.: An Introduction to the Chemistry of Plant Products. Longmans, Green and Co., second edition, London and New York, 1917.

HISS, PHILIP H. and ZINSSER, HANS: A Text-book of Bacteriology. D. Appleton and Co., New York, 1918.

KOLMER, JOHN A.: A Practical Text-book of Infection Immunity and Specific Therapy. W. B. Saunders Co., Phila., 1917.

LONG, HAROLD C.: Plants Poisonous to Live Stock. Cambridge: at the University Press, 1917.

MARSHALL, CHARLES E.: Microbiology. P. Blakiston's Son & Co., Philadelphia, 1911.

MAY, PERCY: The Chemistry of Synthetic Drugs. Longmans, Green and Co., New York, 1911.

PAMMEL, L. H.: A Manual of Poisonous Plants. The Torch Press, Cedar Rapids, Iowa, Part I, 1910.

PEMBRAY, U. S. and PHILLIPS, C. D. F.: The Physiological Action of Drugs. Edward Arnold, London, 1901.

STITT, E. R.: Practical Bacteriology, Blood Work and Animal Parasitology. P. Blakiston's Son & Co., Philadelphia, 1914.

WELLS, H. GIDEON: Chemical Pathology (second edition). W. B. Saunders Co., Philadelphia, 1914.

Laboratory Work

Suggestion to Teachers.—A supply of small animals can be kept in cages in the basement of the laboratory for the purpose of testing out the poisonous effect of various suspicious poisonous plants. White mice, white rats, guinea pigs, frogs and the like can be kept in captivity. Wild mice and rats caught alive in traps might also be used and the common kinds of pigeons.

A supply of poisonous drugs (carefully safeguarded) should be kept and the various reagents used in testing them also. The laboratory should be equipped with the necessary glass ware, Bunsen burners and chemical apparatus for the use of the class.

Laboratory Exercises

1. Place a thin transverse section of the endosperm of *Strychnos Nux-vomica* on a slide and treat with a few drops of sulphuric acid, if strychnin is present there will be a red coloration of the cell-contents. Place a small crystal of potassium chromate beneath the cover-glass and a violet color will be produced.

2. Place a thin transverse section of the rhizome of the monk's hood, *Aconitum Napellus*, on a slide and treat with a few drops of 50 per cent. sulphuric acid. A carmine red coloration will appear and this is a specific reaction of aconitin found in the parenchyma surrounding the vascular bundles. This reaction is more intense, if the sections have been previously warmed in a sucrose solution.

3. The presence of cyanogenetic glucosides may be detected as follows: Crush the part of the plant in water and set aside for some time, then filter and add to the filtrate a little silver nitrate. If hydrocyanic acid is present a white precipitate is formed.

4. Place thick sections of the plant tissue to be examined in a 5 per cent. alcoholic solution of potash for about a minute then transfer to a solution containing 2.5 per cent. ferrous sulphate and 1 per cent. ferric chloride and keep at about 60°C. for ten minutes. Then treat the section with dilute hydrochloric acid (one part strong acid to six parts of water) for five to fifteen minutes, if hydrocyanic acid is present a blue precipitate of Prussian blue appears.

5. Guignard's test may be used as an alternative with four. White filter-paper is dipped in a 1 per cent. solution of picric acid and dried. When ready to be used moisten the treated papers with a 10 per cent. solution of sodium carbonate and again dry. These test papers should be kept in stoppered bottles. Exposed to the fumes of hydrocyanic acid the paper rapidly changes to an orange-red color as the test is a delicate one.

Experimental Pharmacology

Experiments on the Action of Veratrin (See Greene, Charles Wilson, Experimental Pharmacology. A Laboratory Guide for the Study of the Physiological Action of Drugs, third edition, P. Blakiston's Son & Co., 1909, page 50 and fig. on page 51. This book may be taken as a guide in such experiments. As the time for this course is limited such experimental work should be performed as a class demonstration by the professor and his assistant, rather than as individual student exercises. The work below should be performed as a sample.

1. Veratrin on the frog. The dose for a frog is about 0.5 c.c. of a 1 per cent. solution of the fluid extract of *Veratrum viride*, or 0.3 c.c. of 0.01 per cent. veratrin. Compare with the effects of aconite and barium. See experiment 4.

2. Veratrin on the mammal. Give a cat or rabbit 1 c.c. of 0.1 per cent. veratrin hypodermically, or 1 c.c. of 1 per cent. for a dog. Keep under observation for a considerable time.

3. Veratrin on the heart strip. Subject the contracting strip of ventricle to 0.005 to 0.05 per cent. veratrin in saline.

4. Veratrin on the frog's heart. Pith a frog, expose the heart and take a tracing when perfused with 0.005 per cent. veratrin in Ringer's solution (0.01 per cent. destroys coordination).

5. Veratrin on the isolated mammalian heart. Prepare the apparatus for the isolated heart experiment, isolate a cat's heart and perfuse with 0.0002 per cent. veratrin in Locke-blood solution. See Figs. 4, 5, 6.

6. Veratrin on the simple muscle contraction of the frog. Ligate one leg of a frog and give a hypodermic of 0.05 c.c. of 0.1 per cent. veratrin. After 15 minutes

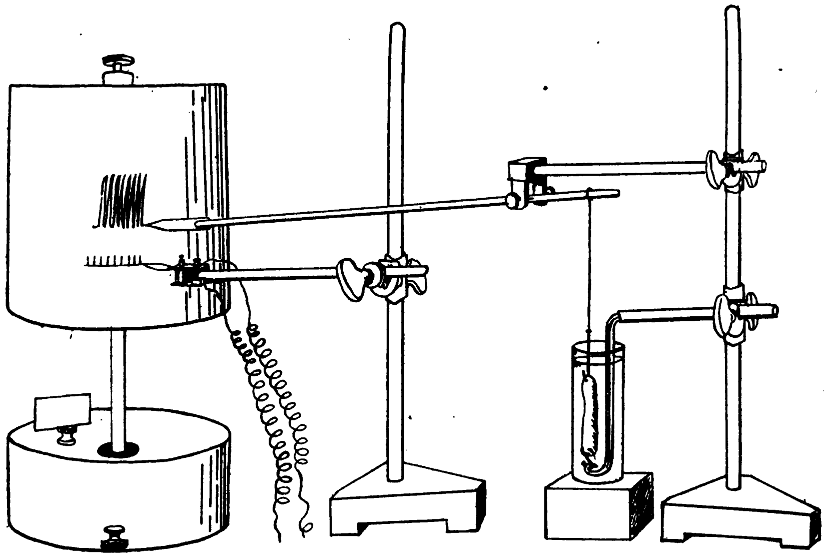


FIG. 4.—Apparatus as set up to demonstrate the contractions of the apex muscle of terrapin's ventricle. The glass L-shaped holder should be set on the stand high enough to allow of easy change of solution tubes. The figure shows the tube of physiological saline and other details for the better illustration of the mounting of the heart strip. (*Greene*).

prepare the veratrinized muscle and take simple muscle contractions to show the form of the contraction wave, using a tuning fork to record the drum speed. Compare this curve with that of the undrugged muscle.

The frog of experiment 1 may be used to show the veratrin effect on muscle work. Stimulate once in three seconds in this experiment, since the relaxation may not be complete in an interval of two seconds.

7. Veratrin on the circulation and respiration of a mammal. Take a record of the blood-pressure from the carotid of an anesthetized dog. Tracheotomize and take respiratory tracings. Give 1 c.c. of 1 per cent. veratrin in the abdominal cavity. When marked cardiac slowing appears cut the vagi and note the effects on the heart.

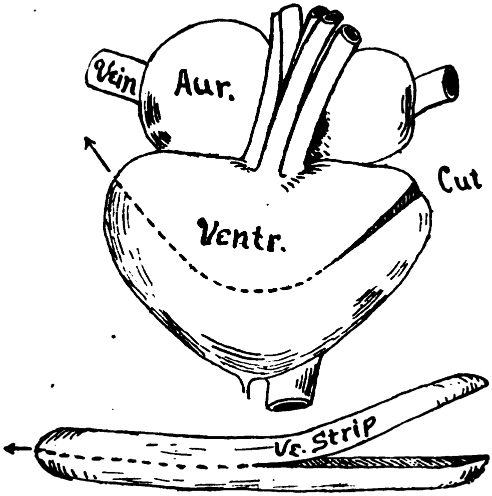


FIG. 5.—The terrapin's heart, ventral view, showing how to cut an apex strip for experimental purposes and how to split this apex into smaller pieces. (*Greene.*)

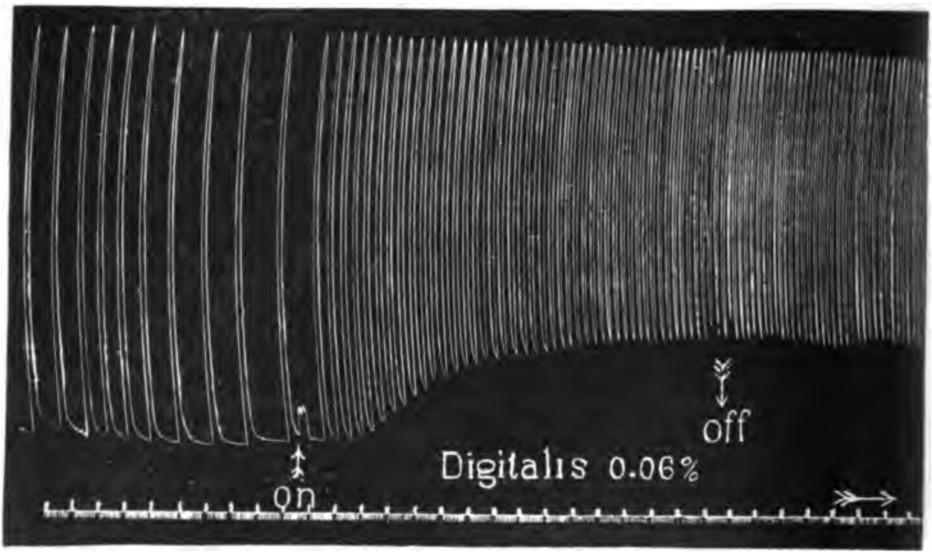


FIG. 6.—Experiment showing the action of digitalis on the rhythm and tone of a strip of terrapin's ventricle. The strip was contracting in physiological saline. Between the words "on" and "off" it was subjected to 0.06 per cent. of digitalis in saline. (*Greene.*)

8. See KOLMER, JOHN A.: A Practical Text-book of Infection, Immunity and Specific Therapy. Philadelphia, W. B. Saunders Company (second edition), 1917, page 898, for the following experiment with phytotoxins: Prepare a 1 per cent. suspension of washed rabbit and guinea-pig corpuscles. Into a series of six small test-tubes place increasing doses of ricin or abrin solution as follows: 0.1, 0.2, 0.3, 0.4, 0.5, and 0.8 c.c. Add 1 c.c. of rabbit-cell emulsion to each and sufficient normal salt solution to make the total volume in each tube equal to 2 c.c. A seventh tube is the corpuscle control and contains 1 c.c. of the erythrocyte suspension and 1 c.c. of salt solution. Prepare a similar series of tubes with the guinea-pig erythrocyte suspension. Shake the tubes gently and incubate for two hours.

Queries.—Do any of the tubes show hemolysis or hemagglutination? Is the action the same with both bloods? Does the plant toxin show a selective affinity?

CHAPTER 3

POISONOUS FUNGI AND OTHER SPORE-BEARING PLANTS

This chapter will deal with the poisonous character of the lower plants, those which form spores instead of true seeds. The bacteria, such as the organisms which produce anthrax and glanders, are not included, because the study of their pathogenicity is elaborated in various works on bacteriology and they are considered as a special phase of medical research requiring an elaborate technique. There are a number of fungi, such as corn smut, *Ustilago Zeæ*, reputed to be poisonous to stock, but such belief needs confirmation. The following fungi have been studied thoroughly and there can be no doubt as to their poisonous action.

Ergot (*Claviceps purpurea*).—The ergot fungus is found on rye both in America and Europe, where during wet, warm weather it may be extremely prevalent. It gains entrance to the host at the base of the young ovary penetrating the ovary wall and gradually replacing the tissues of the rye ovary. This is accompanied by an enlargement of the ovary, which at its upper end presents a somewhat spongy character. This is due to the outgrowth of the mycelium in the form of twisted strands, the marginal hyphæ of which acting as conidiophores abstrict off conidiospores. This early stage was known as the *Sphacelia* stage. Later, as the time for the maturing of the healthy grains arrives the diseased ovaries will be found to be replaced by bluish-black, horn-like bodies which project conspicuously from between the glumes of the rye spikelet. The rye ovary is replaced by a hard body with blackish surface and white interior known as the sclerotium. The ergot spurs, or sclerotia, perennate as such until the following spring, when they send up one or several outgrowths, or stroma, with a knob-like end of a yellowish-brown color. In the hyphal tissue, which comprises the knob-like portion of the stroma, flask-shaped perithecia are formed with short necks and slightly protruding ostioles. The asci contained in these perithecia are elongated and contain eight needle-shaped ascospores, which measure 60 to 70μ in length, and issue from the tip of the ascus by a small opening. These ascospores bud off condiospores, which are capable of infecting the ovaries of rye plants, which have started their growth toward maturity the following season.

Chemical Nature of Ergot.—The ergot spurs are used medicinally under police regulations, for they are dangerous and poisonous. Ergot contains 0.20 to 0.25 per cent. of ergotinin, as an amorphous compound, and the physiologically active alkaloid ergotoxin or hydroergotinin ($C_{35}H_{41}O_6N_5$). When taken in sufficient amounts ergot causes serious

FIG. 7.—Calf No. 2 after being fed diseased "paspalum" heads some days. Note stiff appearance with legs rather wide apart to assist in standing. (*After Brown, H. B. and Ranck, E. M.: Forage poisoning due to Claviceps Paspali on Paspalum. Technical Bulletin No. 6, Mississippi Agricultural Experiment Station,* 1915, *p.* 21.)

poisoning of the domestic animals and man. Extensive outbreaks of ergotism have occurred in the United States. In the Baltic provinces of Germany and Russia, the peasants frequently eat bread made out of flour in which ergot spurs have been ground. They suffer from gangrenous affections of the extremities with a loss of the hair, teeth and finger nails. A nervous form of ergotism has also been prevalent. Cattle eating ergoted grain show similar gangrenous and nervous symptoms, the loss of hoofs, tails and horns. Ergot can be controlled to some extent by the selection of the grain seed and the removal of all ergoted masses, when detected in the fields.

A closely related species, *Claviceps microcephala*, was submitted to the writer by the late Dr. Leonard Pearson on red-top hay in 1902, which had been responsible for gangrenous affection of a herd of cattle at Scranton, Pennsylvania. *Claviceps paspali*, found on grains of *Paspalum* in

Fig. 8.—Calf No. 2. This picture shows animal in stage of excitement during which it cannot remain on its feet. Note peculiar expression of eyes, also the chin resting on the ground to help maintain position. All that was necessary to cause the animal to assume this position was to clap the hands and jump toward it. The nervous paroxysm would immediately come on and last one or two minutes. (*After Brown, H. B. and Ranck, E. M.: Forage poisoning due to Claviceps Paspali on Paspalum. Technical Bulletin No. 6, Mississippi Agricultural Experiment Station, 1915, p. 22.*)

Maryland on *P. læve*, according to J. B. S. Norton, is responsible for the poisoning of cattle in Maryland and Mississippi (Figs. 7, 8, 9, 10).

Symptoms.—The detailed symptoms, as gathered from various sources, are the following: Symptoms referable to the digestive tract such as nausea vomiting, colic, diarrhœa or constipation occur in both the nervous (spasmodic) and gangrenous forms of ergotism. Pregnant animals very frequently abort. In the spasmodic form of the disease, there is an over stimulation of the central nervous system. There is a tonic contraction of the flexor tendons of the limbs, anæsthesia of the extremities, muscular trembling, general tetanic spasms, convulsions and delirium. Death usually occurs from secondary causes.

The gangrenous type of the disease is marked by coldness and anæsthesia of the extremities succeeded by dry gangrene of these parts with loss of the feet, tips of the ears, dropping of the tail, shedding of the hair

FIG. 9.—Calf No. 2. Note that the entire lower jaw, neck, and breast are used by the animal in maintaining this peculiar position. Note also that the eye is partially closed and drawn; this is very different from the first symptoms noticed. (*After Brown, H. B. and Ranck, E. M.: Forage poisoning due to Claviceps Paspali on Paspalum. Technical Bulletin No. 6, Mississippi Agricultural Experiment Station, 1915, p. 24.*)

and teeth, etc. Exhaustion is the cause of death in this form of ergotism. Acute poisoning is characterized by profuse salivation, dilatation of the pupils of the eyes, rapid breathing and frequent pulse with vomiting (in dogs). The animal cries out, has twitchings of the convulsive sort, staggering gait, paraplegia, intense thirst and coma, followed by death.

Golden-rod Rust (*Coleosporium solidaginis*).—This fungus is found as a rusty outbreak on the leaves of various Compositæ, such as *Solidago* *canadensis*, *S. rigida*, *S. serotina* and as *Vernonia noveboracensis*, the iron-weed. Horses have been poisoned in New Jersey and in Wisconsin by eating golden-rod and the trouble has been attributed to the presence of this rust fungus in growth on the plant. The disease has baffled veterinarians, but the fact that horses have remained healthy when feeding in pastures without golden-rod, or when they are driven from pasture before the golden-rod appears seems significant. The attention of the

FIG. 10.—Calf No. 2 prostrate. Note drawn expression of eyes and slight drawing back of head (aposthotonus). In this condition the animal breathes rapidly, shows consciousness, and responds to noise by twitching. (*After Brown, H. B. and Ranck, E. M.: Forage poisoning due to Claviceps Paspali on Paspalum. Technical Bulletin No.* 6, *Mississippi Agricultural Experiment Station*, 1915, *p.* 25.)

writer was first called to this fungus in material received from Newfield, N. J., on Sept. 22, 1900.

Symptoms.—The symptoms are general dullness, ears drooped, temperature elevated ranging from 103° to 107°F. during the entire course or the disease. The visible mucous membranes are pallid and spots are seen. The legs of the animal become swollen and œdematous enlargements appear under the abdomen. The spleen is enlarged, weighing from xis to ten pounds. Blood disintegrated. The appetite is fairly good, but emaciation begins as the disease advances. There is loss of coordination and death takes place in from two weeks to two months from the onset of the disease.

Description of Fungus.—The fungus is characterized, as follows: The uredosori are rounded, soon become powdery and scattered. The uredospores are orange colored produced in short chains. They are spherical, oblong or subcylindrical and spiny, 20–35 × 15–20μ. The

FIG. 11.—*Amanita muscaria.* (*After Patterson, Flora W. and Charles, Vera K.: Mushrooms and other common fungi. Bull.* 175, *U. S. Department of Agriculture,* 1915, *Fig.* 3.)

teliosori (teleutosori) are at first orange, later becoming red. They are flat, often confluent and form frequently waxy crusts. The teliospores (teleutospores) are cylindrical or somewhat clavate, generally four-celled, 60–70 × 15–25μ.

Fly Agaric, Fly Poison (*Amanita muscaria = Venenarius muscarius*). This is a fleshy toadstool widely distributed in woods, the borders of woods and thickets in temperate regions, being especially abundant under and near pine trees. It is a striking plant and because of its showy character and beauty additionally dangerous. Its colors are paler in this country than in Europe. The cap, or pileus, is convex-globose, flattening out as it expands and from eight to twenty centimeters broad with a slightly viscid surface when fresh and slightly striate margin. The color varies from red, or orange, to yellow and sprinkled with numerous whitish-yellow flakes. The gills, or lamellæ, are white, rather broad, reaching the stalk or stipe and slightly decurrent upon it. The spores are white, subglobose to ellipsoid $9–10 \times 7–8\mu$. The stipe is stuffed, or hollow usually rough with scales and in color white, or pale yellow. The base of the stipe is bulbous and the white, or yellowish volva breaks up early so that it is rarely seen. The superior annulus is large, membranous, white and persistent (Fig. 11).

Chemical Nature of Poison.—The fly agaric was so called because decoctions of it were used for killing flies. The active poisonous principle of chief interest in this fungus is an alkaloid muscarin, although Kobert finds two other alkaloids cholin and a third fungous atropin. Muscarin ($HON\ (CH_3)_3CH_2CH(OH)_2$) is a substance with tobacco-like odor and an extremely violent poison, .003 to .005 of a gram (.06 grain) being a very dangerous dose for a man. The amount of this poison varies with soil and climate. Cholin when oxidized is converted into muscarin, and if it is subject to bacterial decomposition, it is changed to neurin an extremely poisonous base. Hence old, partially decomposed specimens of fly agaric are more actively poisonous than fresh ones.

Symptoms.—V. K. Chestnut sums up the symptoms, as follows: "Vomiting and diarrhoea always occur, with a pronounced flow of saliva, suppression of the urine, and various cerebral phenomena beginning with giddiness, loss of confidence in one's ability to make ordinary movements, and derangements of vision. This is succeeded by stupor, cold sweats, and a very marked weakening of the heart's action. In cases of rapid recovery, the stupor is short and usually marked with mild delirium. In fatal cases, the stupor continues from one to two or three days, and death at last ensues from the gradual weakening and final stoppage of the heart's action."

Treatment.—The preliminary treatment should be the administration of an emetic, such, as sulphate of zinc, or tepid mustard water, and afterwards the use of a strong purgative, so as to remove all traces of the offending substance. The hypodermic injection of atropin ($1/100$ to $1/60$ of a grain) should then be made, as it is an almost perfect physiological antidote for muscarin (Fig. 12). Many lives have been saved by the use of atropin.

Death Cup (*Amanita phalloides, Venenarius phalloides*).—This handsome, solitary toadstool is found in woods, or along the borders of woods, very rarely indeed in open places. The cap, or pileus, is convex companulate and later expanded from three to fifteen centimeters broad. The upper surface smooth, slightly viscid when moist and decorated with fragments of the universal veil. Its color is pure white to yellow, yellowish-green, green, gray, brown or blackish with a usually entire margin, rarely striate. The taste is not objectionable but the odor is disagreeable. The lamellæ are broad and white, rounded at the base, free or adnexed to the stipe. The spores are globose, hyaline 7–10μ. The floccose-scaly stipe is bulbous at the base and stuffed, or hollow. The superior annulus is thin, membranous and ample. The basal volva is white attached to the base of the large, rounded bulb (Fig. 13).

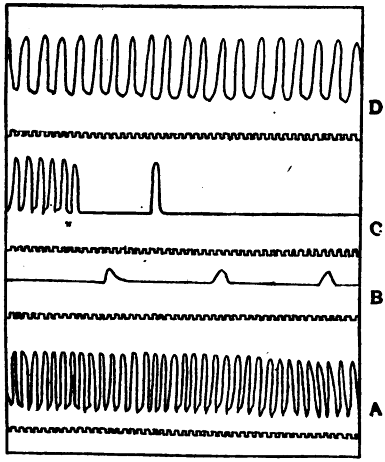


FIG. 12.—Contraction of a frog's heart: *A*, normal; *B*, three minutes after the application of one drop of a 10 per cent. solution of muscarin; *C*, at the point indicated by the star two drops of a 10 per cent. solution of muscarin were applied. Two minutes after the end of this curve the heart commenced to contract again with a slow and feeble beat. *D*, three minutes after the application of a weak solution of atropin sulphate in normal tap-water saline. It will be seen that the rhythmic contractions are restored and the contraction and relaxation become so complete that the excursion of the lever is greater than in Curve *A*, but the frequency is less. The time is marked in seconds. (*Adapted from Pembrey, M. S. and Phillips, C. D. F. The Physiological Action of Drugs*, 1907, *Figs.* 52 *and* 53, *pp.* 76–77.)

Poisonous Substances.—*Amanita phalloides* owes its toxic properties to at least two poisonous constituents. One is a powerfully hemolytic agent which is destroyed by heating thirty minutes at 65°, acting directly upon the red blood corpuscles, even, if removed from the serum. Ford and his associates have shown that this hemolysin is a glucoside, and this belongs to the saponin group, yielding on hydrolysis pentose and volatile bases, and yet capable of acting as an antigen, since actively antihemolytic sera can be produced by immunizing animals such as rabbits. Such rabbits can be immunized to extracts of *Amanita phalloides* and the serum of such rabbits will neutralize five to eight times the lethal dose for guinea-pigs, and is anti-hemolytic for the hemolysin of *Amanita*, when diluted to 1–1000. As he and Abel had found this hemolytic poison of *Amanita phalloides* to be a glucoside, this observation is to be interpreted as a successful production of an antibody for a non-protein poison, a glucoside. This substance corresponds to the phallin of Kobert, which is usually given as the active principle of this deadly toadstool. Wells suggests that probably this hemolytic poison is not the important agent in poisoning by *Amanita phalloides*, as it is easily destroyed by heat and the digestive fluids. The thermostable poison, ***amanita-toxin***, gives no reactions for either glucosides, or proteins and does not confer any antitoxic property to the blood of immunized animals. Amanita-toxin kills acutely, the animals dying in 24–48 hours, and showing no changes beyond a fatty degeneration of the internal organs. The hemolysin kills slowly in three to ten days, causing local edema and hemoglobinuria.

FIG. 13.—*Amanita phalloides*. (*After Patterson, Flora W. and Charles, Vera K.: Mushrooms and other Common Fungi, Bull.* 75, *U. S. Department of Agriculture*, 1915, *Fig.* 2.)

Symptoms.—V. K. Chestnut gives a synopsis of the symptoms of poisoning by *Amanita phalloides*. "The fundamental injury is not due, as in the case of muscarin, to a paralysis of the nerves controlling the action of the heart, but to a direct effect on the blood corpuscles (see above) These are quickly dissolved by phallin, the blood serum escaping from the blood vessels into the alimentary canal, and the whole system being rapidly drained of its vitality. No bad taste warns the victim, nor do the preliminary symptoms begin until nine to fourteen hours after the poisonous mushrooms are eaten. There is then considerable abdominal pain and there may be cramps in the legs and other nervous phenomena, such as convulsions, and even lockjaw or other kinds of tetanic spasms. The pulse is weak, the abdominal pain is rapidly followed by nausea, vomiting, and extreme diarrhoea, the intestinal discharges assuming the "rice-water" condition characteristic of cholera. The latter symptoms are persistently maintained, generally without loss of consciousness, until death ensues, which happens in from two to four days." There is no known antidote by which the effects of phallin can be counteracted, but the experiments immunizing rabbits against this poison suggest profitable lines of experimentation in which man may be ultimately immunized.

Helvellic Acid.—Helvellic acid from *Helvella esculenta* has the empiric formula $C_{12}H_{20}O_7$. It is a deadly poison soluble in hot water, so that if the fungus is boiled in water and the water thrown away, the toadstool becomes harmless. Helvellic acid, if intravenously injected, produces hemoglobinuria and icterus with hemoglobulin infarcts in the kidneys. The symptoms of poisonous by this substance resemble in a marked degree those of the deadly phallin, the dissolution of the red corpuscles of the blood being one of the most marked and most dangerous. This is accompanied by nausea, vomiting, jaundice and stoppage of the kidneys. No antidote is known for helvellic acid.

General Considerations.—Mushrooms may be injurious to man even if poisonous varieties are not eaten by habits of gluttony and gormandizing, where large quantities of food are ingested. There is the greatest difference with regard to the digestibility of such fleshy fungi. Some can digest them readily, others find considerable difficulty. When not properly digested by ferment action deleterious products may be formed in the gastro-intestinal tract. Spoiled fleshy fungi may through the action of bacteria develop a ptomaine called cholin $C_2H_4OHN—(CH_3)_3OH$, which becomes an active poison when oxidized.

Groups of Poisonous Fungi (Roch's Classification.—As this chapter has dealt with the fleshy fungi and as questions of poisoning by them is of general interest, the classification of the Dr. Roch from the clinical standpoint, as given in a paper by Beaman Douglass summarizing his work, will be found useful in elucidating the matter. Dr. Roch has made six groups.

Group 1.—*Fungus exciting Action of Muscle Fiber.*—Ergot of rye, *Claviceps purpurea,* which causes strong contraction of the muscles especially of the uterus and the blood vessels, belongs to this group.

Group 2.—Fungi containing a Hemolytic Substance. Gyromitra esculenta, which has caused ten deaths in Europe within ten years, and *Amanita phalloides* possess hemolytic powers.

Group 3.—Fungi producing Gastro-enteritis. This class includes such forms as *Panus stipticus*, *Boletus sensibilis*, *Cantharellus aurantiacus*, *Lepiota Morgani*, *Russula emetica*, *Lactarius torminosus*, *Stropharia*, *Amanita muscaria* and all peppery tasting Russulæ and Lactarii. The usefulness of these forms is doubtful, but if boiled in acidulated water (1 cup vinegar to a pint of water) for ten minutes, washed afterwards and all liquids thrown away, this class may be cooked and eaten with safety.

Group 4.—Fungi affecting chiefly the Nervous System and the Gastro-intestinal System. This group includes *Boletus luridus*, *Amanita cothurnata*, *A. muscaria*, *A. pantherina*, *Clitocybe illudens*, *Inocybe infida* and perhaps *Pholiota autumnalis*. These poisons affect the brain and spinal cord. Roch states that *Amanita muscaria* does not deserve its bad reputation and states emphatically that it does not kill. He recalls the fact that in Russia it is eaten freely, if the cap is peeled and the fungus soaked in acidulated water. In Siberia also the natives use the poison of this plant in religious ceremonies to produce cerebral intoxication, excitement and ectasy. He points to the fact that the poison is eliminated from the body by the kidneys with great rapidity and that in order to continue this cerebral debauch the dose is frequently repeated by drinking the excretion. The lesser symptoms are like a real alcoholic, or cocaine, intoxication; excited heart action, dizziness, laughing and crying, a desire to jump and dance, to run and sing. The devotees of muscarin are perfectly happy, they are in high spirits, experience religious ectasy and this is all increased by ocular hallucination, in which distances are greatly increased, and size is distorted. They also have delightful visions of singing birds, palaces and beautiful landscapes. Roch states, however, that to meet death in this class the sufferer must have eaten *Amanita pantherina*. He states that poisoning by *Amanita muscaria* results in 100 per cent. recovery. These statements are in direct contradiction of those usually accepted (see ante) and should be carefully reinvestigated.

Group 5.—Stimulating only the Nervous System. Panæolus campanulatus, *P. venenosus*, *P. retirugis* and *P. semiglobatus* are included here.

Group 6.—Fungi causing Cell Destruction after a Prolonged Incubation. The fungi of this group cause a destruction of certain cells of the body after a prolonged period of unmanifested activity and are therefore extremely dangerous and usually fatal. There are only eight species belonging to this terrible class, viz.; *Amanita phalloides*, *A. solitaria*, *A. virosa*, *A. vena*, *A. citrina*, *A. mappa* and *Amanitopsis volvata*. Two poisons are found in fungi of this class: phallin and amanitatoxin which have been discussed as to their activity on a previous page.

Horse-tail (*Equisetum arvense*).—This fern plant has underground rhizomes divided into nodes and internodes. Short secondary roots arise from the subterranean nodes which are surrounded by brown, whorled scale leaves. The first shoot to appear early in the spring is chlorophylless with internodes and nodes. A whorl of brown scale leaves arise from the nodes. The summit of this shoot terminates in a sporangiferous cone consisting of sporophylls bearing bag-like sporangia filled with green spores covered by four hygroscopic elaters. Later a green, branching shoot arising from the rhizome and persists through the season (Fig. 14).

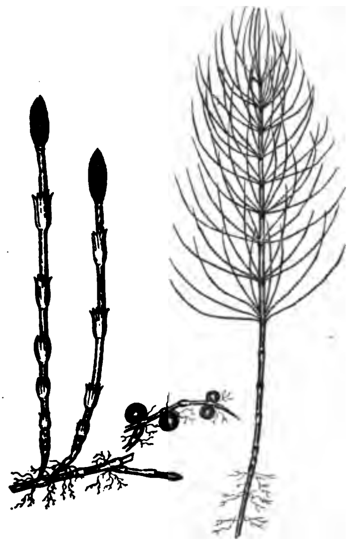


FIG. 14.—Horsetail (*Equisetum arvense*). The pale fruiting stalks at the left come up in spring, the much-branched stalk at the right is the green summer form which occurs in the hay; in the center are the underground stems and tubers. (*After Jones, L. R.: Vermont Grasses and Clovers*, *Bulletin* 94. *Vermont Agricultural Experiment Station, May*, 1902.)

Cases.—The investigations of Rich and Jones show that the horse-tail causes much and frequently fatal poisoning of horses in Vermont. During the summers of 1901 and 1902 Rich in his professional work about Burlington had twenty-three cases of horses poisoned by this plant and his records showed forty-one cases which he had attended within five years. In Europe a number of cases of equisetosis have been reported.

Symptoms.—The first evidence of trouble is more or less an emaciated conditions. The animal in two to five weeks loses control of its muscles, sways and staggers about. Later it has paralysis of the hind legs and as a result it falls down. Attempting to rise the horse becoming nervous struggles violently to arise. Finally there is general paralysis, unconsciousness and coma. The lungs and kidneys become congested, the pulse slow and toward the end rapid and weak. There is sugar in the urine. Death may come suddenly or be postponed in chronic cases for several weeks.

Poisonous Principle.—According to Lohmann there is probably an alkaloidal nerve poison in species of *Equisetum* called by him equisetin.

Treatment.—Stop the feed containing horse-tail, follow with a purgative pill of one ounce of Barbadoes aloes, one or two drachms of ginger, and sufficient soft soap to make a ball. This is put down the throat of the horse at one dose following with bran mashes night and morning until the digestive tract is cleared. Nux vomica is later administered to overcome the muscular incoordination.

Bibliography

Atkinson, George Francis: Mushrooms Edible, Poisonous, etc. Andrus & Church, Ithaca, N. Y., 1900, pages 52–76; 242–252.

Brown, H. B. and Ranck, E. M.: Forage Poisoning Due to Claviceps Paspalin Paspalum. Technical Bull. 6, Mississippi Agricultural Experiment Station, Feb., 1915.

Douglass, Beaman: Mushroom Poisoning. Torreya, 17: 171–175, October, 1917; 207–221, December, 1917.

Ford, W. W.: The Toxins and Antitoxins of Poisonous Mushrooms, Amanita phalloides. Journ. Inf. Dis., 3: 191; The Distribution of Poisons in Mushrooms. Science, 30: 97–108.

Haas, Paul and Hill, T. G.: An Introduction to the Chemistry of Plant Products. Longmans, Green and Co., New York and London, 1917.

Harshberger, John W.: Ergotism Account of an Outbreak at Scranton, Pa., due to Eating Red Top, *Agrostis vulgaris* with *Claviceps microcephala* (Walh.) Tul., Rept. Pa. Dept. Agr., 1902: 160; A Text-book of Mycology and Plant Pathology. P. Blakiston's Son & Co., Philadelphia, 1917.

Long, Harold C.: Plants Poisonous to Live Stock. Cambridge at the University Press, 1917.

McIlvaine, Charles: One Thousand American Fungi. The Bowen-Merrill Company, Indianapolis, Ind., 1900.

Murrill, William Alphonso: Edible and Poisonous Mushrooms. New York, 1916.

Pammel, L. H.: A Manual of Poisonous Plants. The Torch Press, Cedar Rapids, Iowa, Part I, 1910; Part II, 1911.

Rich, F. A. and Jones, L. R.: A Poisonous Plant the Common Horsetail (*Equisetum arvense*). Bulletin 95, Vermont Agricultural Experiment Station, June, 1902.

Scott, J. L.: Golden-rod Killing Horses. Garden and Forest, viii: 477–478, November 17, 1895.

Wells, H. Gideon: Chemical Pathology. W. B. Saunders Company, Philadelphia and London (second edition), 1914.

WILSON, A. STEPHEN: Observations and Experiments on Ergot. Gardeners' Chronicle new ser., iv: 774, Dec. 18, 1875; 807, Dec. 25, 1875.

LABORATORY WORK

Suggestions to Teachers.—A supply of ergot spurs should be kept in dried state for the examination of the class. Ergoted rye heads should be kept in sufficient quantities for class use. The teacher should gather as many specimens of *Amanita muscaria* and *A. phalloides* as possible and preserve these in alcohol for class use. For the chemical tests, the teacher should have pure cholin, phallin and muscarin.

LABORATORY EXERCISES

1. Draw and examine closely the ergoted heads of rye noting the relationship of fungous sclerotia and rye host.

2. Study cross section of the ergot sclerotia stained with Bismarck Brown and mounted in balsam.

3. Draw and study fresh (if obtainable) or alcoholic specimens of fly agaric (*Amanita muscaria*) and death cup (*Amanita phalloides*).

4. Mount spores from these two fungi for microscopic comparison.

5. If time permit paraffin sections of the cap and gills of one or both fleshy toadstools can be given to the class for study.

6. Test for cholin (after Haas and Hill).

A. Boil a strong aqueous solution; decomposition ensues and trimethylamine is given off, which may be recognized by its fish-like smell.

B. Add platinic chloride to the aqueous solution; a double platinum salt is formed which crystallizes on standing. The crystals are soluble in 15 per cent. alcohol. Should the crystals not appear, proceed as follows: Dissolve cholin in alcohol and add alcoholic solution of platinic chloride. Filter off the yellow precipitate, wash with alcohol and dissolve in as little water as possible. Place the solution in a watch glass and stand in a desiccator. Hexagonal plates will be deposited.

7. In order to detect very small quantities, Rosenheim recommends the following method (Journ. Physiol., 33: 220, 1905). Prepare the double platinum salt, place a drop or two on a glass slip, and allow to evaporate. Add a drop of solution containing 2 grams of iodine and 6 grams of potassium iodide in 100 c.c. of water and examine under the microscope. Dark brown prisms or plates will appear and then disappear as evaporation takes place. They will reappear on adding another drop of iodine solution.

EXPERIMENTAL PHARMACOLOGY

(See Greene, Charles W., p. 55)

1. Ergot on the frog. Give 0.5 c.c. of the fluid extract of ergot.

2. Ergot on the heart muscle. Change a contracting heart strip from saline to a 10 per cent. solution of Squibb's fluid extract of ergot in saline solution. Allow it to act for five minutes. Take a continuous record.

CHAPTER 4

GYMNOSPERMOUS POISONOUS PLANTS

The plants treated of in this chapter are members of the division of seed plants, *Spermaphyta*, but their seeds are naked at maturity not inclosed in some seed vessel, or fruit. They are mostly resinous shrubs and trees with evergreen leaves (the deciduous cypress and larch being exceptions). They are included with Class GYMNOSPERMÆ, which comprises the sago palm (*Cycas*), ginkgo, yews, pines, junipers, etc. within its confines.

Yew (*Taxus canadensis*).—This low spreading shrub is found in woods from Newfoundland to New Jersey, southeastern Pennsylvania on north-facing slopes and Virginia west to Wisconsin, Iowa and Minnesota. It contains the bitter-tasting alkaloid, taxin ($C_{37}H_{52}NO_{10}$) which acts as a heart depressant. The plant on account of its reputed poisonous character is called poison hemlock in some places. The bark leaves and seeds are all poisonous. The reddish, sweetish aril surrounding the seeds is not poisonous and is eaten freely by fruit-loving birds.

Cases and Symptoms.—Many cases of poisoning and of death of animals from eating the fresh foliage have been recorded in the veterinary journals, and yet there are contradictory statements as to the results of eating the foliage of this spreading bush. The symptoms of poisoning are: Death may be sudden, resembling apoplexy. It may be preceded by staggering and convulsions and in cases of long standing there is gastro-enteritis. "There is a pronounced slackening of respiration and circulation, the pulse being small, slow. Sensibility is diminished. There is a fall of temperature, the skin and extremities being cold. The head is lowered, the eyes are closed and there is decubitus. In some cases pregnant animals have aborted. In the horse, there are muscular tremors and frequent urination. In cattle and sheep rumination is suspended and there is more or less pronounced tympanites, with eructation, nausea and sometimes vomiting. Pigs bury the head in the litter and sleep, their sleep being interrupted from time to time by nausea and groaning; or the animals rise, stagger about, and lie down again. With fatal quantities the foregoing symptoms may be followed by coma with death in two hours or more after the poisoning, but more generally and usually in horses, asses and mules (but also in cattle) there is no period of coma, the excitement is less pronounced and often unobserved, and death appears very sudden. The animals stop, shake their heads, respiration is modified, there is falling, and death (sometimes with convulsions) results from cessation of the heart's action" (Cornevin).

The western yew (*Taxus brevifolia*) is also said to be poisonous, as also the English yew (*Taxus baccata*) with much circumstantial evidence against it.

Common Juniper (*Juniperus communis*).—This plant is poisonous and yields a poisonous oil obtained from its berries. Rusby refers to the poisonous nature of the plant and Schaffner records that goats are poisoned by eating its foliage. It grows on limestone and sandstone in the northern United States and Rocky mountains.

Red Cedar (*Juniperus virginianus*).—This is a tree of wide distribution from New Brunswick to British Columbia, south to Florida, Texas, New-Mexico and Arizona. Dr. Halsted has reported that goats have been poisoned by browsing upon it.

Redwood (*Sequoia sempervirens*).—Redwood leaves are said to be poisonous. The tree is confined principally to the coastal region of California.

Bibliography

Garratt, Thomas and Radclyffe, W. F.: The Yew Poisonous to Cattle. Gardeners' Chronicle and Agricultural Gazette, 1872, 715 (May 25).

J. G. J. S.: Yew Poisoning. Gardeners' Chronicle and Agricultural Gazette, 1872, 509 (April 13)

Long, Harold C.: Plant Poisonous to Live Stock. Cambridge at the University Press, 1917, 72–76.

Pammel, L. H.: A Manual of Poisonous Plants. Part I, 1910, 101–102; Part II, 1911, 325–332.

Sohn, Charles E.: Dictionary of the Active Principles of Plants; Alkaloids; Bitter Principles; Glucosides. Balliére, Tindall and Cox, London, 1894.

Watney Helen G. Yew Poisoning. The Garden, vii, 311, Apr. 10, 1875.

Wittstein, G. C. and von Mueller, Baron Ferd: The Organic Constituents of Plants and Vegetable Substances and Their Chemical Analysis. M'Carron, Bird & Co., Melbourne, 1878.

Laboratory Work

1. Study and draw dried specimens of eastern American yew (*Taxus canadensis*) or western yew (*T. brevifolia*) or the redwood (*Sequoia sempervirens*).

2. Study and draw the aril and sectioned seeds of the yew shrub previously preserved in alcohol.

3. Study and draw branches, berries, etc., of the red cedar (*Juniperus virginiana*) similarly preserved.

4. Taxin obtained by purchase from the analytical chemist, is a white, loose amorphous powder, very bitter, slowly soluble in water, readily in alcohol and ether, fusible to a yellow resin by gentle heat, soluble in dilute acids. It should be kept as a stock supply for the following tests which should be performed by each member of the class. Precipitate by caustic alkalis and tincture of iodine. Test with concentrated sulphuric acid which produces a purplish-violet color. This color can be decolorized with water.

CHAPTER 5

MONOCOTYLEDONS AS POISONOUS PLANTS

The poisonous plants treated of in this chapter belong to the Monocotyledoneae. Botanically the class is distinguished, as follows: The permanent roots are secondary being produced adventitiously, or at the time of embryonic development. The sap bundles in the stem are scattered and are closed, that is, each one is surrounded with a bundle sheath of sclerenchyma, which prevents further enlargement of the bundle. The principal veins of the leaves are parallel. The floral symmetry is of the trimerous kind and the embryo, usually surrounded with reserve food, possesses only one seed leaf, or cotyledon.

Fodder or Silage Poisoning.—Two grasses are considered responsible for poisoning when fed as dry fodder or silage. These grasses are maize, or Indian corn (*Zea Mays*) and sorghum(*Andropogon Sorghum*). The author is not aware that any profound investigation has been made of the exact conditions under which poisoning is to be attributed to cattle eating fodder, or silage. Two alternatives seem to be possible. Corn stalks and the stems of sorghum are not easily digestible and the impaction of their fibers in the digestive tract may bring on severe cases of indigestion, especially where the cattle do not have access to plenty of water. The other alternative is in the poisonous action of toxic substances developed in the stored maize, or sorghum. It is known, that when corn silage is not properly stored, that is, where air has free access to all parts of the silage, that prussic acid develops. A glucoside occurs in the maize stem and this is capable of being converted into hydrocyanic acid, HCN, by an enzyme in the plant. After periods of extreme drought in the case of sorghum, the leaves of the plant contain considerable quantities of hydrocyanic acid. This acid is an extremely toxic substance being the most rapidly acting drug we possess. Lethal amounts paralyze the respiratory center and the heart muscles, death, as a rule, being due to failure of respiration with almost simultaneous cessation of the action of the heart.

Twenty-one head of cattle, out of a total number of 32 animals, were poisoned at Aurora, Colorado on August 3, 1901 by eating Kaffir corn, a form of sorghum in which considerable amounts of prussic acid were detected. Eleven head lived, but four had violent spasms, but recovered. The symptoms were drowsiness, running at the eyes, twitching of the muscles, numbness of the limbs, staggering gait, inability to stand, involuntary passing of the urine and feces. The statement was made that the cattle seemed to all go crazy at once, then stagger like a person intoxicated, fall in all directions and die where they fell.

Pellagra.—Pellagra has in the past been attributed to eating mouldy corn, or maize. Pellagra is a severe and chronic skin disease occurring among the squalid and destitute, who live largely, as in the southern states, upon maize, or Indian corn. The disease begins in the spring being characterized by eruptions over the entire body associated with indigestion and diarrhoea. The skin exfoliates and ulcerates and the person loses flesh. The disease occurs in southern Europe, in northern Africa and among the "crackers" of the southern United States and the inmates of insane asylums and state penitentiaries. The disease has been attributed to eating spoiled corn, to a colloidal silica in the food, but the current view is that it is due to the lack of vitamines in the food. These are present in minute quantities, but are essential to health. When they are absent from food the nutrition is at once affected and a deficiency disease results. Scurvy, beri-beri and pellagra belong to this class. The lack of one vitamine causes scurvy, the lack of another beri-beri, while the absence of a third in certain foods like corn causes pellagra. This seems to be the latest and most satisfactory explanation of the cause of the disease.

Darnel (*Lolium temulentum*).—The injurious character of this grass at least from its weedy side have been known since early times, for in the New Testament attention is drawn to the tares and the wheat. It is an annual grass with smooth stems growing from 2–3 feet tall with rough leaf sheaths and short ligule. The spikes are 6 to 12 inches long and the spikelets 5–7 flowered. The lower glumes are sharp pointed, equally in length the spikelets, and the lemma is awned, or awnless.

Symptoms.—The grains of darnel, when ground up with wheat and made into flour, show their poisonous effects in producing headaches, drowsiness, giddiness, uncertain gait, and stupefaction, in older animals convulsions, loss of sensation and death. Loliin is the narcotic principle occurring in the pure state as a dirty white, amorphous, bitter substance causing, according to Hackel, eruptions, trembling and confusion of sight in man and flesh-eating animals and very strongly in rabbits, but it does not influence pigs, horned cattle or ducks.

Nature of Poison.—It appears from recent investigation that the grains of darnel, which are injurious, contain a poisonous fungus (*Endoconidium temulentum*) upon which their poisonous effects probably depend. It is believed that grains of darnel without the fungus are not poisonous. The darnel fungus, according to Freeman, lives in the outer layers of the grain penetrating the aleurone layer and invading the starchy endosperm. There exists in the nucellus, at the base of the scutellum of the darnel embryo and at the base and at the lower end of the inner groove a layer of hyphae which lies directly against the embryo, constituting an infective layer. When the embryo pushes out during germination, the hyphae grow into the developing seedling and keep pace with its growth and can be detected in the growing point throughout the life of the plant.

FIG. 15.—Death camas (*Zygadenus venenosus.*) (*After Hall, Harvey M. and Gates, Harry S.: Stock Poisoning Plants of California. Bull.* 249, *University of California Agricultural Experiment Station,* 1915, *p.* 227.)

Death Camas (*Zygadenus venenosus*).—The Indians of the northwestern United States were acquainted with the medicinal and poisonous properties of this plant and the earliest white explorers mention it in their journals. At least nine species of *Zygadenus* are poisonous and the above mentioned one may be taken as the type of their action. The plant is also called wild onion, wild leek. It arises from a tunicated bulb and has narrow, erect, basal leaves and a scape, a foot or more high, becoming a spike of yellowish-white flowers, which blossom about June 1st (Fig. 15). It matures its fruit in July and then the whole aerial part of the plant dies down to the ground. It is native to the west from Assiniboia and Neb-

FIG. 16.—Sheep No. 168 at 1.30 P.M., showing weakness in forelegs after being fed Death Camas (*Zygadenus venenosus*). (*After Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Zygadeus or Death Camas, Bulletin* 125, *U. S. Department of Agriculture*, 1915, *Plate V, Fig.* 1.)

raska westward to the Pacific coast. The chief period of danger is in May and June when its dark green leaves are attractive to stock. Cattle are susceptible to the poison and some deaths have been reported, but cases among cattle are uncommon. Swine are said to eat the bulbs without bad results, but horses are poisoned. Sheep are the animals most frequently poisoned (Figs. 16 and 17). Detailed experiments by agents of the United States Department of Agriculture show that the principal symptoms are salivation, nausea, muscular weakness, coma and sometimes

FIG. 17.—Sheep No. 168 at 5.45 P.M., when unable to rise after being fed Death Camas (*Zygadenus venenosus*). (*After Marsh, C. Dwight, Clawson, A. B., and Marsh, Hadleigh: Zygadenus, or Death Camas, Bulletin* 125, *U. S. Department of Agriculture,* 1915, *Plate V, Fig.* 2.)

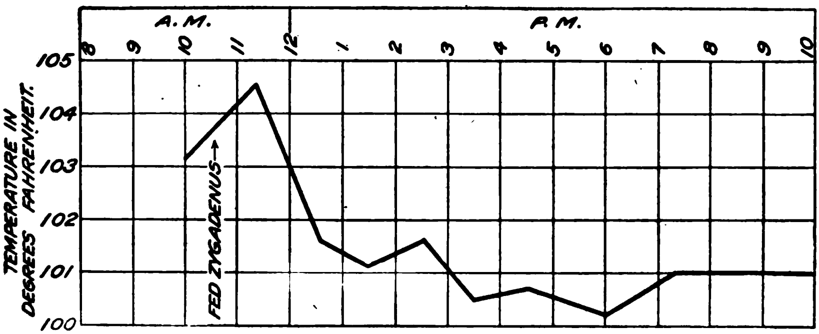


FIG. 18.—Curve of temperature of sheep No. 291 fed on Death Camas (*Zygadenus venenosus*. (*After Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Zygadenus, or Death Camas, Bulletin* 125, *U. S. Department of Agriculture,* 1915, *p.* 26.)

attacks of dyspnœa (Fig. 18). The toxic dose varies according to the conditions of feeding. In drenched animals, it may be put at about one-half a pound for an animal weighing a hundred pounds and in fed animals

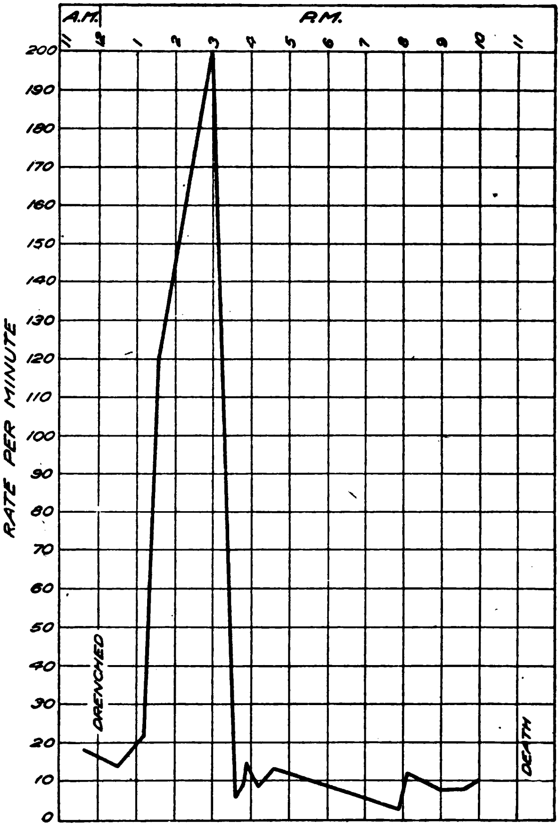


FIG. 19.—Curve of respiration of sheep No. 174 fed on Death Camas, *Zygadenus venenosus*. The sheep was drenched at 12 o'clock noon and died at 11.15 P.M. The respiratory rate rose to 200 between 2 and 3 o'clock, when the animal had one of the spasmodic struggles for breath. It then fell to 9 and remained low, with comparatively slight variations, until the time of death. (*After Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Zygadenus, or Death Camas, Bulletin* 125, *U. S. Department of Agriculture*, 1915, *p.* 27.)

it varies from 1.6 pounds to 5.6 pounds (Fig. 19). The poisonous principle is an alkaloid or alkaloids, allied to veratrin and cevadin. Sick animals should be kept quiet as if this is done there are chances of recovery. No satisfactory medical remedy has been discovered for camas poisoning.

Stagger-grass (*Chrosperma* (*Amianthium*) *muscætoxicum*).—This is an erect smooth herb with a tunicated bulb and numerous long blunt basal leaves. The white flowers are arranged in a dense terminal raceme. The fruit is a capsule filled with reddish-brown, ovoid seeds. It is found in dry, sandy woods from Long Island to eastern Pennsylvania and south to Florida, Tennessee and Arkansas, flowering from May to July. In March 1911, reports were received by the United States Department of Agriculture from Wilmington, North Carolina of the poisoning of cattle by this plant. Feeding experiments conducted by the Marshes and Clawson confirmed the general opinion of the poisonous properties of the fly-poison plant.

White Hellebore (*Veratrum viride*).—This is a common perennial herb in the damp alluvial soil along streams in North America, ascending to 5000 feet in the White Mountains and other eastern ranges. There is a Californian species, *V. californicum*. Its stem is stout, tall, very leafy with broad light green parallel-veined leaves. The flowers are numerous greenish-yellow in a branching panicle. It arises from an erect, underground rootstock. Cases of poisoning are known in man, various animals and birds.

Symptoms.—Animals do not relish the plant, as it is acrid and burning in the fresh condition, but young animals sometimes eat it with fatal results. The seeds have been eaten by chickens with a fatal termination. The most marked symptoms of white hellebore poisoning are burning in the throat and œsophagus, salivation, defective vision, itching, vomiting, diarrhœa, severe headache and death by paralysis of the heart. The number of poisonous substances found in this plant is quite large. Veratrin $C_{32}H_{19}NO_{11}$ has an alkaline reaction and a burning taste, producing violent sneezing and dilatation of the pupil. It has been recently separated into several bases: the very poisonous cevadin $C_{32}H_{49}NO_9$, vetratridin $C_{37}H_{53}NO_{11}$ and sabadillin $C_{34}H_{53}NO_8$ besides sabadin $C_{29}H_{51}NO_8$, sabadinin $C_{27}H_{45}NO_8$, jervin $C_{26}H_{37}NO_3$, rubijervin $C_{26}H_{43}NO_2$, pseudojervin $C_{29}H_{43}NO_7$, protoveratrin $C_{32}H_{51}NO_{11}$, protoveratridin $C_{26}H_{45}NO_8$ and the bitter glucoside veratramarin. Jervin is a powerful depressant of the heart muscles and vasomotor centers. It depresses respiration and death occurs from asphyxiation.

Treatment.—Treatment should consist of the use of cardiac and respiratory stimulants, such as amyl nitrate (by inhalation), alcohol, strychnin, and atropin. Tannic acid can be used as a chemical antidote; opium to subdue pain and demulcents to relieve local irritation of the digestive tract.

Lily of the Valley (*Convallaria majalis*).—The lily of the valley is a smooth, perennial herb with horizontal rhizomes from which arise two or three oblong, parallel-veined leaves. Later in May to June, there is found a short scape with a short raceme of bell-shaped, white flowers having six included stamens. The fruit is a round, red berry with a few seeds. Apparently sheep and goats eat the leaves with impunity. The Revue Horticole published a number of years ago an account of the poisoning of a flock of fowls after eating the decaying flowers of this plant. Only the parent bird survived and one out of ten chickens. Two glucosides are found in the plant. Convallamarin $C_{23}H_{44}O_{12}$ is an extremely poisonous, crystalline compound with a bitter sweet taste. Its physiologic action on the heart is like digitalis. Convallarin $C_{34}H_{62}O_{11}$ is crystalline with sharp taste and purgative in its action. The action of the poisonous principles on the heart is infrequent and irregular. Death occurs from paralysis.

Meadow Saffron (*Colchicum autumnale*).—The autumn crocus is found in meadows in many parts of Europe, but is not known in America outside of gardens. All parts of the plant are poisonous and many horses, cattle and pigs have been killed in Europe by eating it, although sheep and goats are almost immune. Children have died from eating its seeds. The toxic principle is cumulative in its action. It is a poisonous alkaloid colchicin $C_{22}H_{25}NO_6$ which causes after small but not fatal doses loss of appetite, suppression of rumination, salivation, light colic, diarrhoea and voiding of small quantities of urine. Blood has been seen in the milk of poisoned cows. Fatal quantities cause total loss of appetite, stupefaction, loss of consciousness, dilatation of the pupils, unsteady gait, and even paralysis of limbs, sweating, severe colic and bloody diarrhoea, bloody urine; rapid, small imperceptible pulse, labored breathing and death in one to three days. Recovery is very slow, if it takes place.

Red Root (*Lachnanthes* (*Gyrotheca*) *tinctoria*).—This plant occurs in the coastal, fresh-water marshes and cranberry bogs from southeastern Massachusetts, Rhode Island and New Jersey to Florida. It is a tall stout herb with yellow flowers and pink rhizomes. It poisons only white pigs, but not the black ones, so that there develops a preponderance of black pigs over white ones in regions where the plant is abundant. Postmortem examination of the bones of white pigs reveals the curious fact that they are colored a reddish-pink.

Lady Slipper Orchid (*Cypripedium hirsutum*).—This species may be taken as illustrating the poisonous activities of a number of eastern American species of *Cypripedium*. It is found in woods and swamps from Nova Scotia, Ontario and Georgia west to Minnesota and Iowa. The glandular hairs on the leaves, stem and flower parts secrete a poisonous oil which produces an irritation of the skin, or a dermatitis. Mac Dougal, who first reported such poisonous action, experimented personally with a mature specimen and states "a slight tingling sensation was felt at the time, and, fourteen hours later the arm was greatly swollen from the shoulder to the finger tips. The portion covered by the plant was violently inflamed and covered with macules, accompanied by the usual symptoms of dermatitis and constitutional disturbances." Nestler discovered that the secretion of these hairs was a fatty acid readily soluble in alcohol and benzol. No specific antidote has been discovered.

Bibliography

BLACK, O. F. and ALSBERG, C. L: The Determination of the Deterioration of Maize, with incidental Reference to Pellagra. Bulletin 199, Bureau of Plant Industry, U. S. Department of Agriculture, 1910; Contributions to the Study of Maize Deterioration, Bulletin 270, do, 1913.

BLANKINSHIP, J. W.: The Loco and some other Poisonous Plants in Montana. Bulletin 45, Montana Experiment Station, June, 1903, pages 91–93.

HALL, HARVEY U. and GATES, HARRY S.: Stock Poisoning Plants of California. Bulletin 249, College of Agriculture, Agricultural Experiment Station, Berkeley, California, 1915, pages 225–228.

LILY OF THE VALLEY POISONOUS TO FOWLS. Gardeners' Chronicle, 3d Ser., iv, 37.

LONG, HAROLD C.: Plants Poisonous to Live Stock. Cambridge at the University Press, 1917, pages 78–84.

MARSH, C. D.: Stock-Poisoning Plants of the Range. Bulletin 575, U. S. Dept. of Agriculture, 1919, with colored plates.

MARSH, C. DWIGHT, CLAWSON, A. B. and MARSH, HADLEIGH: Zygadenus or Death Camas. Bulletin 125, U. S. Dept. of Agriculture, 1915; Stagger Grass (*Chrosperma muscaltoxicum*) as a Poisonous Plant. Bulletin 710, 1918.

MOORE, VERANUS A.: Cornstalk Disease (*Toxaemia maidis*) in Cattle. Bulletin 10, Bureau of Animal Industry, 1896.

NILES, GEORGE M.: Pellagra An American Problem. Philadelphia, W. B. Saunders Company, 1912.

PAMMEL, L. H.: Manual of Poisonous Plants. Part 2, 1911, pages 333–395.

PELLAGRA DUE TO COLLOIDAL SILICA IN FOOD. Geographical Review, October, 1917, page 321.

PERKINS, W. B.: Sorghum Poisoning of Cattle. Mississippi Report, 1901, page 35.

SORGHUM POISONING (*Sorghum vulgare*) Qu. Agr. Journ., xiii; 59, July, 1903; 98. Aug., 1903, 473; Review Journ. Roy. Hort. Sci., 28, 711.

VITAMINES. The Youth's Companion, June 10, 1918, page 24.

Wilson, Alexander Stephen: Further Experiments with Lolium temulentum. Gardeners' Chronicle & Agricultural Gazette, 1873, 1702–1703 (December 20).

Laboratory Work

Suggestion to Teacher.—Dried specimens with flowers should be kept of each of the plants in the list below and in quantity sufficient to supply each member of the class. These specimens should be made when the material is available, one set of plants should be mounted conveniently for use in demonstration. Darnel with grains, Death Camas, Stagger-grass, White Hellebore, Lily of the Valley, Meadow Saffron, Red Root, Lady Slipper Orchid. As many of these listed plants should be distributed (usually one or two in the single laboratory hour), as can be described conveniently. Selected plants above will be found in the eastern and western parts of America and in Europe (Meadow Saffron).

Laboratory Exercises

1. Describe each specimen according to the accompanying outline, or to the outline with maps and other data in the Students' Herbarium for Descriptive and Geographical Purposes published by Christopher Sower Company, 124 N. 18th Street, Philadelphia, 1901. European and western American botanists can use the species corresponding to those in the above list.

Outline for Study of Plant

Root.—Primary, or secondary, kind (fibrous, fleshy, etc.), shape.

Stem.—Dicotyledonous, or monocotyledonous, size (height, girth, etc.), kind, shape, peculiarities.

Leaf.—Phyllotaxy, stipulate, or exstipulate, petiolate, or sessile, simple or compound, general shape, venation, margin, apex, base, etc.

Flower.—Inflorescence, perfect, or imperfect, complete, or incomplete, regular, or irregular, symmetrical, or unsymmetrical, bracteate, or ebracteate, bracts (kind, etc.)

Calyx.—Aposepalous, or gamosepalous, insertion, aestivation, number of sepals, shapes, etc.

Corolla.—Apopetalous, or gamopetalous, insertion, aestivation, number of petals, shapes, color, etc.

Stamens.—Insertion, relation to each other, relation to other parts, number.

Pistil.—Apocarpous, or syncarpous, number of carpels, ovary superior, or inferior, number of cells, placentation.

Fruit.—Simple, etc.

Seeds.—Albuminous, or exalbuminous.

2. Distribute stained sections of darnel fruit in oil of cloves, or xylol, for the study of the fungus symbiotic in the grain of the plant.

3. Distribute for permanent mounting sections of the stem and of the leaves of the lady slipper orchid to show position and structure of the glandular hairs of the epidermal surface.

CHAPTER 6

DICOTYLEDONS AS POISONOUS PLANTS

The poisonous plants dealt with in the next four chapters are dicotyledons. Dicotyledons are plants with permanent primary root, which produces secondary, lateral roots. The sap bundles are arranged collaterally with pith in the center surrounded with a cylinder of xylem, cambium, bast (hard and soft), cortex and bark. The principal veins of the leaves are arranged to form a net, or reticulum. The floral symmetry is dimerous, trimerous, or pentamerous. The embryo has two seed leaves, or cotyledons. A careful selection has been made of those known to be poisonous to stock. There are in Europe three hundred and fifty plants which are injurious to man and the domestic animals. There are probably as many in America, but the poisonous effect of many have not been demonstrated. Statistics in regard to poisonous plants are lacking, owing to ignorance of the subject and it is, therefore, impossible to give an estimate as to the amount of damage done by these plants.

There are probably more cases of poisoning on the great stock ranges than in the farming regions, because the conditions on the great stock ranges are different. The stock on the great ranges do not have invariably a sufficient amount of food, and this probably leads to the use of plants which with a more abundant supply would be avoided. New sheep, which are totally unfamiliar with the range plants, are brought in from farms and naturally fail to discriminate the poisonous from the harmless food plants. Some believe that alkali waters, when used by stock for drinking purposes, serve as a substitute for salt, and induce an unnatural appetite in the stock, which results in their use of the injurious plant species of the range for food. We are thus introduced to the species of plants which have been chosen to represent the great dicotyledonous class.

Poke or Garget (*Phytolacca decandra*).—The crowberry, chongras or ink plant is a smooth tall perennial growing 5 to 8 feet tall with a thick root, purplish stems, alternate leaves and elongated racemes of greenish-white flowers followed by purple-black berries, which yield juice used as a substitute for red ink (Fig. 20). The plant is a native of the United States, extending from Maine and northern Illinois to Florida westward to Texas, eastern Kansas and southern Minnesota. The young fresh shoots as they appear above the ground are used for greens, but the root should be rejected as it is bitter and poisonous if taken in large amount. The water in which the plant is boiled should be thrown away, as it contains the poisonous substance.

FIG. 20.—Tall plant of Poke (*Phytolacca decandra*) in abandoned manure pit in front of stable at Belmar, N. J., August 23, 1919. The ripe fruits may be seen on close inspection.

Action and Symptoms.—Poke is a violent, but slow acting emetic, vomiting beginning after about two hours have elapsed from the ingestion of the food. It affects the muscles and nerves causing retching, spasms, severe purging and occasionally convulsions. Accidental cases of poisoning have occurred where the root has been mistaken for parsnip and horseradish. A few fatal cases of the poisoning of children have followed the eating of the juicy berries.

Active Principal.—The active principal of poke is an amorphous, bitter and acid substance very similar to if not identical with saponin. The alkaloid phytolaccin occurs in small amount. Nozi reports a toxic substance phytolaccotoxin ($C_{24}H_{30}O_8$). The juice of the berry is a delicate test for acids, when lime water is added to it.

Corn Cockle.—(*Agrostemma githago*).—This is an erect annual herb growing as tall as wheat in the wheat field. It is densely pubescent with whitish, appressed hairs. Its leaves are opposite, linear-lanceolate and acute (Fig. 21).

FIG. 21.—Corncockle (*Lychnis githago*). Common in grain fields. (*Chestnut Division of Botany, U. S. Dept. of Agriculture.*) (*Reproduced in Pammel, L. H.: Some Weeds of Iowa, Bull. 70, Experiment Station, Iowa State College, 1903, p. 326.*)

Symptoms.—If the seeds (Fig. 21*b*) are ground with wheat, they impart to baker's flour a bitter taste and poisonous properties. Fatal results have followed the use of bread containing ground corncockle seeds. A few years ago a number of horses died in a stable connected with one of the larger Philadelphia breweries by eating oats that had come from the bottom of the grain bin. No deleterious substance was found in the sample of oats submitted to the writer for examination except a large number of corncockle seeds and this indirect evidence points to these seeds as responsible for the death of the animals and a report was made to the owner of the horses accordingly. It is known that the symptoms of poisoning in horses is yawning, heavy colic, stamping and evacuation of rather soft feces. If larger quantities are eaten there is salivation, frequent yawning and turning of the head with colic, pale mucus, hurried and weak pulse, rise in temperature and accelerated respiration. There are muscular tremors followed by rigidity and the feces are diarrhœic and fetid. The horse lies down. It gets up painfully. These symptoms are succeeded by coma and death without convulsions. In cattle the symptoms observed one hour after eating are grinding of the teeth, restlessness and abundant flow of the saliva with colic and coughing, a state lasting five to eight hours followed by coma, fetid diarrhœa, rapid respiration and pulse, a gradual loss of motor and sense powers and a progressive decline of the temperature. In twenty-four hours the cattle are dead. Pigs are also susceptible. Young pigs especially so.[1] A chronic form of the disease is known as githagism.

Poisonous Principles.—The poisonous principle in cockle seeds is a glucoside known under different names as githagin, saponin, agrostemin, sapotoxin, smilacin ($C_{17}H_{26}O_{10}$). Seeds contain up to 6.56 per cent. of this principle which is soluble in water and froths like soap when shaken up.

Aconite (*Aconitum columbianum*).—This is the only native American species which may be considered dangerous like the European plant *Aconitum Napellus*, as the other three American species are very local and not very poisonous. The western American aconite, or monkshood, grows at an altitude of 5,000 to 10,000 feet in low grounds near brooks and springs from Montana, Wyoming and Colorado to the sierras.

Symptoms.—Prof. V. K. Chestnut says of this western species: "All of the parts are poisonous, but the seeds and roots are the most dangerous. The active principle is not well known, but chemical and physiologic experiments point to the existence of one or more alkaloids which resemble aconitin. The effect of the poison is characteristic. There is first a tingling sensation on the end of the tongue which gives rise shortly to a burning sensation, and is rapidly followed by a very pronounced sense of constriction in the throat. The choking thus produced is made the more alarming by the retarding effect which the poison has upon the respiration. The tingling and prickling over the entire body is also characteristic. Besides these symptoms there are generally severe headache, abdominal pains, confused vision, vomiting and diarrhœa. Delirium is usually absent. Death ensues from a stoppage of the respiration in from one to eight hours."

Nature of Poisons.—Horses, cattle, sheep, pigs have been poisoned in Europe from eating *Aconitum Napellus*. Cows have died in Victoria. Linnaeus states that it is fatal to cows and goats when eaten fresh, but

[1] The writer had some seeds sent to him on August 23, 1916, from Dr. W. C. Reeder of Rising Sun, Md., which had been taken from the "chop" feed of hogs, that had been poisoned as a result and were vomiting and showing other signs of debility.

in the dried state it is nontoxic to horses. All parts of the European plant are poisonous, but the root is especially so, and next the seeds and the leaves of the plant. The toxicity varies with age and climate, but slightly active when young. It is most active just before the flowers develop. The cultivated plant is less poisonous than the wild, and the poison is partly dissipated upon drying. The plant contains the toxic alkaloid aconitin ($C_{34}H_{47}NO_{11}$) and also aconin ($C_{25}H_{41}NO_9$). Aconite is an extremely valuable drug being used when taken internally as a depressant slowing the pulse and lowering the blood pressure. In over doses it produces death by respiratory paralysis.

Buttercup (*Ranunculus* sp.).—The hands of the writer were poisoned by removing *Ranunculus bulbosus* from 70 per cent. alcohol in which the tops with flowers had been preserved for class study. The inflammation produced on the skin was a typical dermatitis resembling that caused by the poison ivy, *Rhus radicans*. A number of species are known to be poisonous when fresh, but the poisonous principle is volatile and is dissipated on drying the plants, so that hay with included buttercups is nonpoisonous to stock, if fully dried. Boiling the plants also renders them inocuous. The celery-leaved buttercup *Ranunculus sceleratus*, called by the French *Mortaux Vaches* and *Herbe sardonique*, is considered to be the most toxic species, and the toxicity seems to increase up to the time of flowering after which it decreases. The bulbous buttercup seems to vary in its toxic properties having poisonous flowers, while the bulb-like rhizome becomes most harmful in autumn and winter. *Ranunculus Ficaria*, the lesser celandine, has been the cause of the poisoning of three heifers, while cattle have been poisoned frequently by the tall buttercup, *R. acris*.

Poisons.—Most of the species contain an acrid and bitter juice probably identical with anemonin, which has been obtained along with anemonic acid from the acrid crowfoot, *R. acris*. Some toxicologists assert that the poisonous species contain the two alkaloids aconitin and delphinin.

Symptoms.—The buttercups are acrid, burning and narcotic causing irritation of the mucous membrane, the intestinal tract becoming inflamed. According to Cornevin, the celery-leaved buttercup induces colic, gastroenteritis, diarrhœa with black foul-smelling feces, vomiting in animals which can do it, falling-off in milk yield in cows, nervous state, pulse reduction and stertorous respiration, pupils dilated, feebleness, difficult mastication, spasmodic movements of the ears, lips, etc., convulsions, eyeballs sunken. Death follows the convulsions in six to twelve hours.

Larkspurs (*Delphinium Ajacis, D. bicolor, D. camporum, D. Geyeri, G. glaucum* (Fig. 22), *D. Menziesii, D. Nelsoni, D. scopulorum, D. tricorne D. trolliifolium*) are responsible for cases of poisoning. The principle usually increases its virulence with age. Pammel in his "Manual of Poisonous Plants" gives a circumstantial account of each of the principal species of larkspurs, and the feeding experiments which have been tried with each plant. With the exception of the European, *Delphinium Ajacis*,

FIG. 22.—Tall mountain larkspur (*Delphinium glaucum*). One-half natural size. (*After Hall, Harvey M., and Gates, Harry S., Stock Poisoning Plants of California. Bull. 249, University of California Agricultural Experiment Station, 1915, p. 232.*)

all the other species mentioned above are western American (Fig. 23), a few extending into the eastern United States. As the cattle ranges of western America, as in California, include habitats such as moist meadows, gulches, borders of springs, or ponds, open hillsides, sparsely forested areas and the open steppes, we find the species varying with the habitat conditions, and with this we find that next to the loco weed, the larkspurs are the most harmful and poisonous of the plants found on the open ranges (Fig. 24).

Poisonous Principles.—Not all of the species have been studied for their poisonous constituents, but there have been found in *D. consolida* and *D. staphisagria* the alkaloids delphinin $C_{22}H_{35}O_6N$ extremely poisonous and with a bitter taste; delphisin $C_{22}H_{33}NO_5$ poisonous; delphinoidin $C_{42}H_{68}N_2O_7$ poisonous and staphisagrin. Delphinin has a

FIG. 23.—Pass Creek Park, Colo., with low larkspur (*Delphinium Menziesii*) in blossom. (*After Marsh, C. Dwight, Clawson, A. B., and Marsh, Hadleigh: Larkspur Poisoning of Live Stock, Bulletin* 3657, *U. S. Department of Agriculture, September* 8, 1916, *Plate III.*)

local irritative action. Its systemic action is mainly paralytic on the heart and respiration and resembles that of aconitin in many respects. Post mortem examination in poisoning by mouth with this body showed marked reddening of the stomach. Recently in a number of Van Praag's experiments with feeding solutions of Delphinium a marked increase in urinary secretion was noted.

Recently also *Delphinium bicolor*, *D. Menziesii*, and *D. Nelsonii* have been found to yield an alkaloid, delphocurarin, which has been introduced as a substitute for curare in vivisection work, and this introduction is indorsed by Lohmann's work. Methyl delphinin is said also to possess this curare-like action.

Symptoms.—Froggatt states that the common garden larkspur will kill locusts and advises planting them in masses around gardens as a protective measure against insects as the locusts and the grasshopper. Other species kill maggots and ticks.

FIG. 24.—Sheep feeding upon larkspur (*Delphinium Menziesii*). (*After Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Larkspur Poisoning of Livestock. Bulletin* 365, *U. S. Department of Agriculture, September* 8, 1916, *Plate XV, Fig.* 1.)

The animals affected show symptoms similar to those produced by overdoses of aconite. There is general stiffness and irregularity of gait as the first symptoms. The hind legs show pronounced straddling (Fig. 25) and these actions become more pronounced until locomotion becomes difficult or impossible, and the animal finally falls to the ground, making attempts to get upon its feet, the movements being more and more irregular and incoördinated (Fig. 26). The skin is sensitive to the touch and the muscles of the legs and sides of the body begin to quiver spasmod-

FIG. 25.—Case 117, August 15, remaining on its feet with great difficulty. Animal poisoned by eating larkspur. (*After Marsh, C. Dwight, Clawson, A. B., and Marsh, Hadleigh: Larkspur Poisoning of Live Stock. Bulletin* 365, *U. S. Department of Agriculture, September* 8, 1916, *Plate X, Fig.* 3.)

FIG. 26.—Case 117, August 15, in the act of backing in the manner characteristic of larkspur poisoning. Animal poisoned by eating larkspur. (*After Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Larkspur Poisoning of Live Stock. Bulletin* 365, *U. S. Department of Agriculture, September* 8, 1916, *Plate X, Fig.* 4.)

FIG. 27.—Case 78, when feeling the worst. Horse poisoned by eating larkspur. (*After Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Larkspur Poisoning of Live Stock. Bulletin* 365, *U. S. Department of Agriculture, September* 8, 1916, *Plate XIV, Fig.* 3.)

ically and this continues for several hours. The special senses seem to be seldom impaired, hearing and sight are both normal. There is slight salivation. Violent convulsions follow the above premonitory symptoms the animal dying in one of the fits. The digestive action appears normal. There is a slight lowering of the temperature, the pulse becomes frequent and the respiration rapid and shallow. The nervous symptoms are simply those of excitement and the appetite is fair. Cattle and horses are the animals usually killed by eating these plants (Fig. 27). Sheep are rarely injured.

Treatment.—The California Experiment Station recommends the following medicine for subcutaneous injection by a hypodermic syringe.

Physostigmin salicylate, one grain.
Pilocarpin hydrochloride, two grains.
Strychnin sulfate, one-half grain.

These quantities are for an animal weighing five hundred or six hundred pounds. This remedy relieves constipation and stimulates respiration. The dose should not be repeated. Poisoned animals should be kept quiet with the head kept higher than the other parts. Grubbing out the plants has been found to be the best method of preventing loss of cattle from larkspur poisoning.

Marsh Marigold (*Caltha palustris*). This stout, smooth herb is a native of Europe and in America it is found in swamps and meadows from Newfoundland to South Carolina and Nebraska, flowering from April to June. The reports about the plant are most contradictory. In some places, the flower buds are pickled, eaten and used fresh as a pot herb. Stebler and Schroeter say that it is poisonous in a green state, and Rusby states that fed with hay, it produces diarrhœa and stoppage of the flow of milk. Rafinesque asserts that cattle die of the inflammation of the stomach, while it causes hematuria, according to Freidberger and Fröhner.

May-apple (*Podophyllum peltatum.*)—This perennial herb has a long creeping rootstock from which the stem with 2 peltatel eaves arises bearing a single, creamy-white flower with 6 unequal sepals, 6–9 petals, 12–18 stamens and a single-celled ovary.

Symptoms.—The Indians were acquainted with its medicinal virtues and the writer on inquiring the use of the plant of an old negro herb doctor, who was gathering the rhizomes in the woods near Philadelphia, replied, "boss, it is good for the bowels." The old colored man recognized its purgative qualities in small doses. Dr. Winslow says: "The action is exerted mainly on the duodenum, which is intensely inflamed and even ulcerated in poisoning. Podophyllin directly increases the secretion of the bile in small doses, while purgative quantities hasten its excretion by stimulation of the muscular coat of the gall bladder (except in the horse, and small intestines). It is probable that the intestinal secretions are somewhat augmented. The fecal movements after medicinal doses of podophyllin are liquid, often stained with bile, and may be accompanied by some nausea and griping." Eaten by cows, while pasturing in open woodlands, it imparts to the milk of such animals purgative properties, which may be dangerous to infants fed upon such milk contained in the bottle. Cases of poisoning have been reported occasionally. In the Philadelphia Medical and Surgical Reports (XIX: 308), a fatal case is recorded in which the evidence is perfectly clear that poisoning resulted from continual large doses administered by an ignorant and careless physician. The poisonous symptoms were all referable to the intestines as enteritis. Inhalation of the dust of the dried rhizome and administration of podophyllin in ¼ to ½ grain doses cause inflammation of the eyes, soreness and pustulation of the nose; salivation and white-coated tongue; extreme nausea, followed by vomiting; severe pains in the transverse colon and abdomen, followed by a call to stool; thin, offensive, copious stools; weak pulse, prostration, drowsiness, and cold extremities."

Active Properties.—The active properties of the plant appear to reside in the resinous substance podophyllin. This contains podophyllotoxin $C_{11}H_{14}O_2 + 2H_2O$ and picropodophyllin, $C_{11}H_8O_2 + H_2O$ with a bitter taste, berberin $C_{20}H_{17}NO_4$ (feebly toxic to many) and saponin.

Celandine (*Chelidonium majus*).—The celandine is a member of the poppy family (PAPAVERACEÆ) introduced from Europe into America and in some localities thoroughly naturalized. Its leaves are thin once to twice pinnatifid and glaucous beneath. When the rootstock, stem and leaves are bruised, a yellow juice or later exudes. The flowers are yellow with two sepals, four petals and numerous stamens. The ovary is superior, one-celled with two parietal placentæ. It has long been used as a drug plant having emetic and purgative properties and is a dangerous poison. There are no cases on record of domestic animals being killed by eating it, as it has an unpleasant odor.

Properties.—The plant contains a bitter alkaloid chelidonin ($C_{20}H_{19}NO_5$ + H_{20}) and an additional poisonous alkaloid chelerythrin ($C_{21}H_{17}NO_4$) related to sanguinarin and protopin ($C_{20}H_{17}NO_5$). Cornevin states that the poison is not removed by drying the plant, but Pott (1907) believes that it becomes harmless to animals on desiccation.

The plant is acrid, irritant and narcotic, emetic and purgative. Chelerythrin causes violent sneezing, if inhaled, and causes vomiting if taken internally.

Poppies (*Papaver spp.*).—Two old world plants of this genus the corn poppy (*Papaver Rhoeas*) and the long smooth fruited poppy (*Papaver dubium*) are of sufficient interest to be included in our list of poisonous plants, especially as their relationship to the opium poppy (*Papaver somniferum*) enables us to refer to this perhaps the most important plant of a medicinal kind, the source of a useful drug, which properly controlled is beneficial, but if improperly used is the cause of more misery than any other drug employed by mankind.

General Considerations.—Poisoning by the above mentioned poppies is not common, but the corn poppy has been known to poison animals when mixed with green fodder, or by the ingestion of seeds and capsules with waste materials taken in with the food. Ordinarily stock refuse to eat the plants, because they have an unpleasant odor and taste. Horses, cattle and pigs have been poisoned by eating *Papaver dubium*.

The drug acts more powerfully upon man than upon the lower animals, especially ruminants, who are comparatively insusceptible.

Symptoms.—With regard to the symptoms produced in animals, Dr. Winslow says: "Ounce doses of the drug cause, in cattle, restlessness, excitement, hoarse bellowing, dry mouth, nausea, indigestion and tympanites. Sheep are affected much in the same manner. One to two drachms of morphin have led to fatality in cattle. Fifteen to thirty grains of the alkaloid comprise a lethal dose for sheep. Swine are variously influenced, sometimes excited, sometimes dull and drowsy." With horses it sometimes causes drowsiness at other times has no visible effect. Horses have recovered from an ounce of opium, but two and one half ounces of the drug and one hundred grains of morphin have proved fatal.

Cornevin describes the symptoms in cattle as excitement, pawing of the soil or litter, increased respiration and more rapid pulse, followed by stoppage of digestion sometimes with a swelling of the eyelids and coma. Cattle move about with an unsteady gait. Finally the animals fall, and if poisoned fatally, it remains stretched on the ground respiration becomes slower, the temperature falls, with convulsions and death by asphyxia. Müller notes wildness of look, dilatation of pupil convulsions, coma and symptoms of depression. There is bloating, constipation, bloody diarrhœa (at times) and salivation. Death is rare.

Nature of Poisons.—The opium poppy contains a long list of alkaloids enumerated by Flückiger and Hanbury. The most important of the alkaloids is morphin ($C_{17}H_{19}NO_3 + H_2O$) which in the pure state is a colorless or white shining, odorless substance with a bitter taste. Codein, also of considerable importance is a nearly transparent odorless substance with a faintly bitter taste and narcotin is also present.

Wild Black Cherry (*Prunus serotina*).—This is a medium sized forest tree found in the Middle Atlantic and Ohio River states very commonly. Less commonly in southern New England and Gulf states and westward from Illinios, South Dakota, eastern Nebraska and Arkansas. The leaves are alternate and dark green. The white flowers, which appear in April and May, are produced in racemes, followed in the fall by the shining-black, edible fruit, suggesting a small bunch of grapes.

Nature of Poisoning.—Poisoning is frequently caused in cattle by eating the wilted leaves from branches, which have been accidently broken off from the tree. A case of poisoning in horses on a stock farm at Chestnut Hill, Pa., was called to the attention of the writer, where the animals in passing from the paddock, where they had been feeding, to the stable had browsed upon the leaves from several branches that had been broken down by the passing of a wagon loaded with hay. The prominent symptoms observed in cattle are labored breathing, diminished pulse, numbness, protruding eyeballs, convulsions, and death from paralysis of the lungs. Sometimes there is frothing at the mouth and nearly always a perceptible odor of prussic, or hydrocyanic, acid on the breath.

Active Principles.—The fresh parts of the plant, including the leaves, are nonpoisonous, but contain a glucoside called amygdalin ($C_{20}H_{27}NO_{11}$) when the leaves are partially withered this glucoside is acted upon by a ferment known as emulsin, and by a complex chemical change, the amygdalin is converted into the poisonous prussic, or hydrocyanic acid (HCN) with the formation of grape sugar and benzaldehyde (bitter almond oil). It is the formation of the hydrocyanic acid, which causes the poisoning, and if the leaves are thoroughly dried the prussic acid, being volatile, is dissipated, and they become harmless.

Other Poisonous Species of Prunus.—Several other species of the genus *Prunus* similarly become poisonous. Among them are the cherry laurel (*Prunus laurocerasus*) of Europe, wild red cherry (*Prunus pennsylvanica*), found in rocky woods from Newfoundland to the Rocky mountains to Georgia, and *Prunus demissa* found on river banks from British

Columbia to Idaho and California, also in the Black Hills of South Dakota. Many cases of poisoning have been recorded from persons eating the seeds of bittei almonds and peaches.

Bibliography

ALDOUS, A. E.: Eradicating Tall Larkspur on Cattle Ranges in the National Forests. Farmers' Bulletin 826, U. S. Department of Agriculture, August, 1917.

ANON.: Poisoning of Cattle by Acorns. Gardeners' Chronicle & Agricultural Gazette, 1870, 482 (September 5).

ANON: Uses and Distribution of the Pokeberry (*Phytolacca decandra*). The Garden VI, 508–509, Nov. 28, 1874.

CHESTNUT, V. K.: Principal Poisonous Plants of the United States. Bulletin 20, Division of Botany, U. S. Department of Agriculture, 1898, pages 21–27; Preliminary Catalogue of Plants Poisonous to Stock. Annual Report, Bureau of Animal Industry, 1898, pages 398–403; Thirty Poisonous Plants of the United States. Farmers' Bulletin 86, U. S. Department of Agriculture, pages 9–14; Some Poisonous Plants of the Northern Stock Ranges. Yearbook of the U. S. Department of Agriculture, 1900; 314–318.

CHESTNUT, V. K. and WILCOX, E. V.: Stock-poisoning Plants of Montana. Bulletin 26, Division of Botany, U. S. Department of Agriculture, 1901, pages 65–80.

CRAWFORD, ALBERT C.: The Larkspurs as Poisonous Plants. Bulletin 111, Part 1, Bureau of Plant Industry, U. S. Department of Agriculture, 1907.

HALL, HARVEY M. and GATES, HARRY S.: Stock Poisoning Plants of California. Bulletin 249, College of Agriculture, Agricultural Experiment Station, Berkeley, California, 1915, pages 229–232.

HARSHBERGER, JOHN W.: *Ranunculus acris*, An Additional Poisonous Plant. Botanical Gazette, 19, 159; Garden and Forest, 7, 170.

LONG, HAROLD C.: Plants Poisonous to Live Stock. Cambridge at the University Press, 1917, pages 9–21, etc.

MARSH, C. D.: Stock Poisoning Plants of the Range. Bulletin 575, U. S. Dept. of Agriculture, 1919 with colored plates.

MARSH, C. D., CLAWSON, A. B. and MARSH, H.: Larkspur Poisoning of Live Stock. Bulletin 365, U. S. Department of Agriculture, Sept. 8, 1916.

MARSH, C. D., CLAWSON, A. B., MARSH, H.: Larkspur or Poison Weed. Farmers' Bulletin 988, U. S. Department of Agriculture, 1918.

PAMMEL, L. H.: Manual of Poisonous Plants, Part II, 1911, pages covering description of the above mentioned plants.

Laboratory Work

1. The students with the outline of plant description before them should describe fresh, or dried, specimens of the poke, corncockle, aconite, butter cup, marsh marigold, larkspur, mayapple, columbine, poppy and wild black cherry. Flowers of these plants

can be kept in alcohol for winter study and many of them can be obtained in Europe and in eastern and western America.

2. Apply the delicate Dunstan and Carr test for aconitin. A dilute solution of the alkaloid, even 1 part in 4000 parts of water, faintly acidulated with acetic acid, deposits a red crystalline precipitate or the addition of a few drops of solution of potassium permanganate. This reaction is quite characteristic and extremely delicate.

3. Morphin dissolved in concentrated sulphuric acid containing formaldehyde (2 drops of 40 per cent. solution to 3 c.c. of sulphuric acid) produces a fine violet to almost blue coloration (Marquis, 1900).

4. Experimental work in pharmacology following the directions of Charles W. Greene, Experimental Pharmacology, pages 15 and 48, can be made with morphin and aconite.

CHAPTER 7

LOCO WEEDS AND OTHER POISONOUS PLANTS

Black Locust—(*Robinia pseudo-acacia*).—This is a tall forest tree of eastern North America with a rough bark, pinnately compound leaves. Its papilionaceous flowers are white, sweet-scented and borne in pendulous racemes. Its wood is hard and during the world war, 1914–18, was much sought after to make the wooden pins used in building the emergency fleet of wooden vessels. The bark and leaves of this tree contains a powerful poison which has proved fatal in a number of cases. The bark of this tree contains a toxic albumose and a toxic glucoside, named robitin, which has now been isolated by B. Tasaki and U. Tanaka. In the fresh bark one per cent. of the glucoside is present, and the toxic reaction is caused by a dose of 0.0015 gram in the horse and 0.02 gram in cattle. The reaction of robitin when injected into horses is exactly that produced by the fresh bark, and consists in dyspnœa, increase of secretions and excretions and paralysis of the hind quarters. The seeds also are poisonous.

Symptoms.—The symptoms of poisoning are like those produced by belladonna and this is manifested in the cases of several horses that ate the bark off the tree for the animals had colic, tympanites and paralysis. The most prominent case where human beings were poisoned is given by Dr. Z. P. Emery. In March 1887, thirty-two boys inmates of the Brooklyn Orphan Asylum were poisoned at one time by eating the bark of the tree. The symptoms were the vomiting of a ropy mucus, flushing of the face, dilated pupil, dryness of the throat, feeble pulse, extremities cool, face pale, vomiting of blood, cold extremities, heart feeble and intermittent, face deathly pale with stupor. A rash similar to that of belladonna poisoning was present, but only temporary. A high-fever was noticed in the beginning. The treatment consisted of sinapisms over the stomach, subcarbonate of bismuth, camphor and brandy.

Broom(*Cytisus* (*Sarothamnus*) *scoparius*).—This European shrub is rather uncommon in America, but on Nantucket, Naushon and elsewhere it has been planted to hold embankments. It has also become adventive on the Pacific coast. The tough, wiry stems are dark green and the leaves are trifoliate. The alkaloid in the plant is cytisin $C_{11}H_{14}N_2O$ which occurs also in other species of *Cytisus* and in some other leguminous plants. Spartein ($C_{15}H_{26}N_2$), as a volatile alkaloid, if administered to rabbits in single doses, is sufficient to produce death. The symptoms of poisoning are those of narcotics resembling coniin, which causes paralysis of the central nervous system.

Burma Bean (*Java Bean, Paigya,* (*Phaseolus lunatus*).—As some cargoes of Burma beans were found to be of a poisonous character, the Burma Department of Agriculture was urged to encourage the cultivation of beans containing less cyanide than *Phaseolus lunatus*. As the result of experiments reviewed in Bulletin 79 of the Agricultural Research Institute, Pusa, it has been found that the Madagascar beans are not suitable for replacing the Pe-gya and Pe-byangale beans so largely grown in Burma, and moreover after two years cultivation their prussic acid content increased. From tests made with common cultures of the Paigya bean, it is concluded that those with a low hydrogen cyanide content give low figures when grown in different localities, but the content varies considerably with different soil and climatic conditions. The Prussic acid is developed from a cyanogenetic glucoside, phaseolunatin ($C_{10}H_{17}O_6N$). The colored forms of beans yield the largest amount of hydrocyanic acid.

FIG. 28.—Lupine (*Lupinus leucophyllus*). One-half natural size. (*After Hall, Harvey M. and Gates, Harry S.: Stock Poisoning Plants of California. Bull.* 249, *University of California Agricultural Experiment Station*, 1915, *p.* 237.

Lupines (*Lupinus* spp.).—The lupines have been known from the earliest times and their value as a fodder crop was recognized. Bread was also made out of lupine meal by the ancient Egyptians. Pliny mentions the use of lupine seeds in medicine. Poisoning by lupines were noted as early as 1860, but in 1872, following heavy losses of sheep in northern Germany, considerable attention was given to the poisonous properties of lupine hay. In this country from 1899 on, the experimental studies of Chestnut, Wilcox, the Marshes and Clawson have thrown considerably light upon the subject of lupinosis (Fig. 28).

Loss of Animals.—Sheep have mainly suffered from feeding upon the lupines and the losses have been heavy, but horses, cattle, goats, swine and fallow deer have been poisoned and experiments with small animals show that none were immune to the toxic substances. The losses in Europe have in some years been very great. In 1880 in Pomerania, the loss of sheep was almost 6 per cent. The loss of sheep in America has been heavy. Chestnut and Wilcox (1901) cite that of 2,000 sheep pastured over a region rich in lupine plants, 1,000 sheep were sick and 700 died. In another locality, 1,150 animals died out of a flock of 2500.

Nature of Poisons.—*Lupinus luteus* the European species, which has been investigated most carefully contains two alkaloids, lupinin ($C_{21}H_{40}N_2O_2$) and lupinidin ($C_8H_{15}N$). Investigations in Europe, however, suggest that these alkaloids are not responsible, but that the active substance is ictrogen formed as the result of the growth of microorganisms upon the plant. Investigation of American species has failed to show the presence of ictrogen, but the American lupines contain alkaloids which are toxic or fatal, if a sufficient quantity of the plant is consumed. The lupine alkaloids produce a stimulation and then paralysis of the respiratory and vasomotor centers, some convulsive centers, the vagus end mechanism and perhaps the vagus center. Large doses given intravenously paralyze the heart muscles. The fatal doses for rabbits by the stomach are between 30 and 50 grams per kg. of the seeds of *Lupinus leucophyllus* and *L. sericeus* and between 70 and 100 grams per kg. for the seed of *Lupinus cyaneus*. The cause of death is paralysis of the respiration. The seeds are the most poisonous, then in order the pods and the leaves.

Symptoms.—Sheep poisoned by lupine froth at the mouth, their breathing is heavy and labored, subsiding into a condition of coma, the animal falling over as in a deep sleep. In acute cases, there is dyspnœa with the tongue and mouth cyanotic and the peripheral blood-vessels congested. Sometimes in these attacks of dyspnœa the animal dies in convulsions. In other cases, the animal dies in coma. The convulsive attacks of dyspnœa, however, may be considered typical of lupine poisoning. Dropping of the ears is an early symptom and in many cases the poisoned animal is continuallly pushing its head against surrounding objects. When affected on the range, they run about in a frenzied way, butting into other animals and objects. If the sheep does not die in the period of excitement, it staggers until it falls, then lies in a stupor, which in fatal cases gradually grows more pronounced. The pulse and respiration are very high in the acute stages of poisoning, but there is no effect on the temperature except in prolonged cases where the temperature

FIG. 29.—Loco Weed (*Aragallus* (*Oxytropis*) *Lamberti*) natural size. (*After Blankinship, J. W.: The Loco and some other poisonous plants in Montana Agricultural Experiment Station,* 1903, *p.* 80, *originally after U. S. Department, of Agriculture.*)

gradually falls to between 98° and 99°F. The symptoms may appear in 1 or 2 hours after the food is eaten, or in other cases nearly 24 hours may elapse. Death may follow quickly, or the animal may live for 2 or 3 days.

The result of autopsies show the peripheral blood vessels strongly congested. The left heart is strongly contracted, the lungs and liver congested. The blood-vessels of the brain are congested, as well, as those of the inner wall of the ileum. With horses the general symptoms noticed are twitching of the surface muscles, constipation, dullness, and a tendency when walking to lift the fore feet high.

Stemless Loco Weed (*Aragallus* (*Oxytropis*) *Lambertii*).—This is a perennial herb arising from a vertical thick, persistent tap root and with radical, compound leaves with 11–17 narrowly lanceolate leaflets. The racemes are erect, elongate and bear white to dark bluish-purple papilionaceous flowers succeeded by an erect, lance-oblong pod (Fig. 29). The

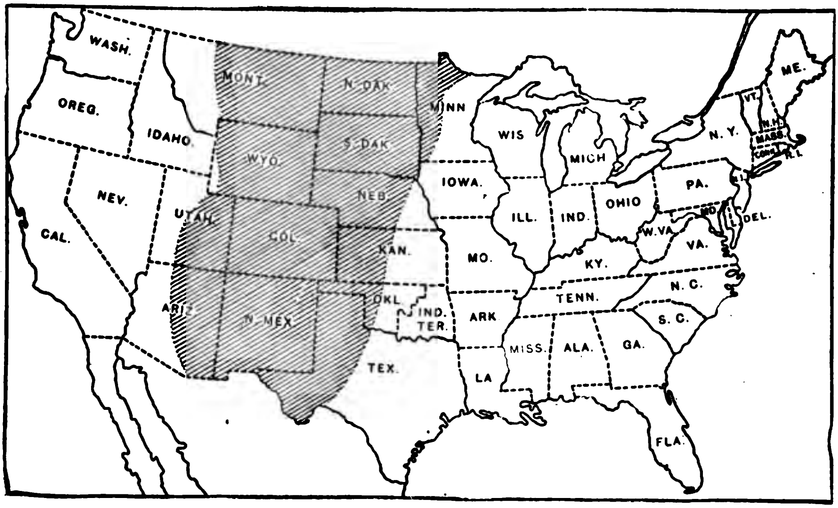


FIG. 30.—Map of the United States, showing the distribution of the stemless loco weed. (*Aragallus Lamberti*). (*After Farmers' Bulletin* 380, 1909, *p.* 9, *The Loco Weed Disease*.)

plant is distributed over the plains region from Alberta and Assiniboia in Canada south into Mexico, and from Minnesota and Kansas westward to the Rocky mountains (Fig. 30). Plants bloom in Colorado in the latter part of April. In parts of Colorado, Wyoming and Montana at the time of flowering, large areas are as white as though covered with snow (Fig. 31).

Wooly Loco Weed (*Astragalus mollissimus*).—This perennial herb is frequently designated as "stemmed," because it has a leafy stem, which is somewhat decumbent, bearing compound leaves with 23–29 leaflets covered with silky-villous hairs, hence wooly. The bright-purple papilionaceous flowers are borne in short racemes and are followed by cylindric pods about 2 cm. long. The geographic distribution of this plant partly overlaps that of the first mentioned loco weed. It ranges from South Dakota south to Mexico and through western Nebraska, Kansas, Oklahoma, Texas, nearly the whole of New Mexico, eastern Arizona, Colorado and southwestern Wyoming. It grows on adobe soils in depressions rather than in elevated situations, occurring in patches covering several

FIG. 31.—Stemless loco-weed (*Aragallus* (*Oxytropis*) *Lamberti*) on cattle range of the western plains. (*After photograph reproduced as cover illustration of Marsh, C. Dwight: The Loco-weed Disease, Farmers' Bulletin* 1054, *July*, 1919.)

acres, rather than in continuous stretches of country. It blooms in Colorado about June 1, but further south in New Mexico, it flowers as early as April.

Blue Loco Weed or Rattleweed (*Astragalus diphysus = Cystium diphysum*).—This perennial herb is more western and southwestern in its distribution than the other two loco weeds. It ranges through Colorado, New Mexico, Arizona extreme southern Nevada and southern California, and is the common loco weed, or rattleweed, of New Mexico and Arizona.

It is very different in its appearance from the former two loco plants. The stems are ascending, or decumbent, 2–4 in. high becoming small ovate to oblong leaflets, 19–21 in number to each compound leaf. The plant has in its vegetative condition a rough resemblance to alfalfa. The flowers are produced in a dense spike and are blue, purple, or violet in color. The pods are inflated, hence bladder-like and in the immature sta e are streaked with purple.

Loco Weeds in General.—The three plants described above are usually considered together as loco weeds. They have occasioned the poisoning of horses, cattle and sheep in the field. The wooly loco weed poisons horses generally, and is rarely injurious to cattle, which will not eat the plant

FIG. 32.—Case 8. Steer pastured on stemless loco-weed (*Aragallus Lamberti.*) Showing the effect of the plant in leaping unnecessarily high in going over a rut in the road. (*After Marsh, C. Dwight: The Loco-weed Disease of the Plains, Bulletin* 112, *Bureau of Animal Industry, Plate III, Fig.* 4, *June* 28, 1909.)

readily. Horses as a rule begin to feed upon the plant when they are short of food. Both the wooly and stemless loco weeds are green during the winter, when all the plains grasses are dry and brown. Hence, they are especially dangerous in the spring, when the horses and cattle are turned out to pasture. Once the animals feed upon the plant, they acquire the habit and this shows the development of a depraved appetite, which was attributed by some to the presence of tape worms.

Symptoms.—The symptoms of poisoning in horses are quite marked. A high-spirited horse becomes dull followed by irregular gait and irregular mode of feeding. The horse drags its feet more or less (Fig. 33). Associated with this partial paralysis is an apparent loss of muscular control

FIG. 33.—Case 525. Horse showing peculiar gait which is exhibited by an animal which has been locoed. *After Marsh, C. Dwight: The Loco-weed Disease of the Plains, Bulletin* 112, *Bureau of Animal Industry, Plate V, Fig.* 3, *June* 25, 1909.)

FIG. 34.—Case 525. Locoed horse rearing when suddenly startled by a hat thrown out in front of it, August 23, 1905. This horse was very poor, being little but skin and bones, with rough coat and shaggy mane and tail. (*After Marsh, C. Dwight: The Loco-weed Disease of the Plains, Bulletin* 112, *Bureau of Animal Industry, Plate V, Fig.* 4, *June* 25, 1909.)

the animal stepping high (Fig. 32) in approaching a stone; or a rut in the road, and shies at imaginary objects (Fig. 34). As the disease progresses, the animal seeks solitude, rearing up if approached. The jaws have a stiff motion in eating, or drinking. The animal loses flesh, its coat becomes rough, it ceases to eat and soon dies. The symptoms of locoed cattle are similar to those of locoed horses. There is the same lack of muscular control, a violently shaking head, frantic running into obstructions. A locoed animal is almost impossible to drive, as it is likely to run into the driver, and in the opposite direction. Locoed cattle have staring eyes, rough coats and gradually lose flesh. They go to water less and less frequently and eventually die of starvation.

The symptoms of poisoning in sheep are not so marked as with horses and cattle. Locoed sheep are generally more weak, stumbling, falling and rising again with difficulty. Post-mortem examinations show accumulations of coagulated serum in a gelatinous form in various parts of the body especially about the heart and spinal column. The nervous system in locoed animals is more richly supplied with blood than in normal animals.

Cause of Locoism.—The specific cause of poisoning by loco weeds was sought early in the presence of some toxic substance, in the plants, but chemical analysis failed to reveal such. Recourse was then made to the presence of tapeworms in the alimentary tract of various animals, but these can hardly be the real cause of the characteristic symptoms of locoism. Dr. Albert C. Crawford from his laboratory work concludes; "The symptoms in stock on the range can be reproduced in rabbits by feeding extracts of certain loco plants. It is the inorganic constituents, especially barium, which are responsible for this poisonous action. There is a close analogy between the clinical symptoms and pathological findings in barium poisoning and those resulting from feeding extracts of certain of these plants. Small doses of barium salts may be administered to rabbits without apparent effect, but suddenly acute symptoms develop analogous to those reported on the ranges." Marsh dismisses the previously suggested causes of the disease, other than the plants themselves, as having no reasonable basis as to render them tenable. The administration of sulphates, especially epsom salts to form the insoluble barium sulphate, is suggested by the above discovery of the inorganic cause of the loco disease. The dose used in experiments with mature cattle was about one pound given in the form of a drench. For horses, the dose should be about 8 ounces and for full-grown sheep 4 ounces. To improve the nervous condition of the horses, Fowler's solution in daily doses of 4 to 6 drams in the drinking water was found best. The use of strychnin was found best for cattle. Sodium cacodylate administered hypodermically to cattle in injections of 6 grains, or 0.4 gram, daily gave beneficial results. Recovery is generally shown with chronically locoed animals. Loco weeds may be destroyed by cutting off below the crown of buds, because sprouting is rendered impossible.

Rattle-box (*Crotalaria sagittalis*).—This is an annual plant growing 3 inches to a foot high with small straight root and branched stem with yellow flowers and an inflated pod, which finally contains a lot of loose seeds which rattle about when the pod is dry. The plant is distributed from Maine to Minnesota, South Dakota, Iowa, Nebraska, and northern Texas. It is very common on the sandbars of the Missouri River, hence the disease produced by it which resembles in general that induced by loco weeds, is known as the Missouri Bottom Disease. Animals have been locoed by eating rattle-box in New Jersey.

Box (*Buxus sempervirens*).—This is a tall, evergreen shrub with small, dark-green, leathery, elliptical leaves. The flowers are small and rather inconspicuous. The shrub has been used for hedges in old-fashioned gardens and has been much planted in cemeteries. All parts of the plant are bitter and poisonous. Animals, horses and pigs, may browse upon box, or eat the hedge trimmings and be killed. Buxin is the toxic alkaloid, while three other substances have been isolated from the plant. Small amounts of box have an emetic and purgative action. The symptoms of poisoning are nervous symptoms, lameness, muscular tremors, vertigo, then a period of coma. Large amounts cause death preceded by intense abdominal pains, dysentery, tenesmus, convulsions, circulatory and respiratory troubles. Pigs are most susceptible displaying thirst, uncertain movements, delirium. Death occurs in twenty-four hours.

Spurges (*Euphorbia* spp.).—The spurges are erect, spreading or prostrate herbs, with milky, acid juice and opposite, or alternate leaves, the upper in whorls and frequently colored at the tops. The acrid, milky juice is poisonous, but poisoning cases are rare because cattle usually rarely eat of them because the taste is repulsive. *Euphorbia marginata* is one of the many species in the United States. In Texas, it is used in the branding of cattle. The seeds of this species have proved nearly fatal to children that have eaten them. Dr. Millspaugh gives the physiological action of the caper spurge (*Euphorbia Lathyris*) as staring, wide-open eyes, dilated pupils, death-like pallor, retching and vomiting, violent purgation, frequent stools, copious and in some cases bloody, irregular pulse, whole body cold and rigid, succeeded by heat and perspiration. Country people in England have used the fruits of this plant as a purge and as a pickle, but their poisonous character renders them dangerous. Cows that have eaten of the spurges give a reddish or sharp-tasting milk and the milk of affected goats caused diarrhœa in human beings.

Castor Oil Plant (*Ricinus communis*).—The palma christi is an annual plant in temperate regions, but in the tropics it becomes a small, perennial tree. Its leaves are large, broad, palmately lobed and veined. Its flowers are borne in separate clusters, as pistillate and staminate on the same plant. The fruit is covered with soft spines and the seeds contained therein are provided with a terminal spongy mass of tissue, the carunculus. The seeds are albuminous with an oily reserve food. The oil expressed from the seeds is the medicinal castor oil with strongly purgative properties. The seeds, as a whole, are poisonous and were used in Europe by farmers to poison recalcitrant sheep, that developed the habit of jumping fences into strange pasture fields. Pigs and poultry have been poisoned by eating the seeds. The press cake was the cause of the death of 80 sheep, as reported by M. Audibert near Beaucaire, France.

Poisonous Principles.—Ricin is the toxic body similar to bacterial toxins. Animals can be immunized by the use of an antitoxic body antiricin. Ricinin ($C_8H_8O_2N_2$) is an alkaloid obtained from the seeds. Its toxic action is doubtful. Symptoms of poisoning appear some days after ingestion of the beans or press-cake. Purging is marked. In the case of horses, they lose their appetite, shiver, have cold extremities, dejection, abdominal pain, constipation with a temperature of 103°F. and a pulse of 70. Death follows in about three days.

Poison Ivy.—(*Rhus radicans, Rhus Toxicodendron*).—The poison ivy is a vine which climbs up the trunks of trees by short aerial roots, or grows in a spreading prostrate manner over the ground, over stone piles, or the dunes along the seashore. An upright form of the plant is occasionally seen. Its leaves are trifoliately compound, lustrous green turning to a red in autumn. Its flowers are greenish-yellow and its drupaceous fruits white. The plant is poisonous at all seasons of the year as the writer has been poisoned in midwinter by forcing his way through brush over which this ivy had grown. It is especially virulent after a rain on a hot summer's day, when one is actively perspiring. Contact with the plant seems to be necessary to induce poisoning. There is a current belief that the wind blowing toward a person from a patch of poison ivy is sufficient to produce the usual rash on the skin of susceptible persons, but in all likelihood such persons have crushed the plant under foot and in removing their shoes before going to bed have removed the active principle from the surface of the leather. They may also have inadvertently touched the plant in passing by it. The smoke from brush fires in which poison ivy has been placed will cause inflammation of the skin of face and hands. Susceptible persons in our large department stores, who unpack lacquer ware imported from Japan, frequently have the characteristic dermatitis, as the lacquer is made from the juice of a Japanese sumach, *Rhus vernicifera*, and the toxic oil is partially freed from the surface of the lacquered objects during their transportation in closed cases in which steaming may occur from one country to another in the holds of ocean steamers. The southern shrub, *Rhus Toxicodendron*, was formerly considered to be identical with the poison ivy, but recently the two species have been separated as *Rhus radicans* and *Rhus Toxicodendron*. The poison ivy ranges from Nova Scotia to Minnesota, Florida, Arkansas and Nebraska, while the shrubby, *Rhus Toxicodendron*, the poison oak, is found from North Carolina south to Florida and southwestward to Texas.

A third shrub, known as poison sumach, poison oak, poison elder, poison dogwood, thunder-wood is *Rhus Vernix* which is found in swamps from Ontario and Minnesota south to Florida and Louisiana. It is more virulent than the other two species mentioned above. It grows to be a small freely branching tree. It has large pinnately compound leaves, panicles of greenish yellow flowers and large, white, shining drupes produced in open clusters. The California poison ivy, *Rhus diversiloba* is found on the Pacific Coast from California to Washington. It is an erect, or climbing, nearly smooth shrub with compound leaves of three to five leaflets and flowers in loose axillary panicles with white fruit. A key will enable one to distinguish these four species of *Rhus*.

Eastern and Southern Species.

A. Leaves trifoliate; vines or low shrubs.
  Vine climbing by aerial roots.
    Drupes 5–6 mm. in diameter. *Rhus radicans*
  Upright shrubs.
    Drupes 6–7 mm. in diameter *Rhus Toxicodendron*

B. Leaves pinnately 7–11 leaflets; tall shrub, or small tree *Rhus Vernix*.

Western Species (*Pacific Coast*)

Leaves trifoliate to 5-foliate *Rhus diversiloba*. *Rhus Metopium*, poison wood or doctor-gum of the south is a tree with poisonous juices.

Susceptibility.—As hundreds of persons are poisoned every year by coming into contact with these plants, it is important to discover the causative principle. Immunity from the attack of the poison of these species is relative. Some persons usually those with a blonde complexion are very susceptible. Others are less so, while a large number of persons usually with dark, or swarthy complexions (brunette type) are practically immune.

Active Principle.—Experiments (1897) of Dr. Franz Pfaff of Harvard University Medical School have shown that the poison is a fixed oil, toxicodendrol, closely allied to cardol from the cashew-nut, *Anacardium occidentalis*. It is soluble in alcohol, ether, benzene, and chloroform. It produces an insoluble compound with lead. It is found in all parts of the plants described above. It is insoluble in water and therefore cannot be washed off the skin with water alone.

The active principle is poisonous to the skin causing inflammation and pustular eruptions known as dermatitis. Small watery vesicles appear on the skin of the hands usually on the soft skin between the fingers. These vesicles may be scattered in mild cases, as they may be very numerous. Usually the eruptions are accompanied by inflammation and itchiness, and the tendency is to scratch the inflamed areas. In severe cases the pustules cover extensive areas with a swollen condition of the parts and redness. Occasionally, if the skin about the eyes is poisoned, the eyelids swell so that the eyes are entirely closed. Later the vesicles are ruptured and their fluid contents are discharged upon the surface forming moist, excoriated surfaces covered in part with crusts. Where the inflammation reaches the mucous membranes of the internal organs by way of the excretory passages the consequences may be very serious. Death has been the result of ivy poisoning in relatively a few cases.

Remedies.—The most efficient remedy that has been found is a vigorous washing and scrubbing of the skin of the affected parts with soap and water using a brush for the purpose. This washes off the poisonous oil before it has a chance to act upon the skin. The oil may also be removed by washing with alcohol, but the washing must be thorough in order not to spread the infection. Such simple remedies as washing the skin with hot salt water, rubbing the juices of rib grass (*Plantago lanceolata*) the leaves of touch-me-not (*Impatiens*) and bean leaves upon the part exposed to the poison have been used. They are beneficial, although perhaps not curative in their action. Dr. Pfaff recommends the use of an alcoholic solution of sugar of lead (50 or 70 per cent. alcohol). The writer has used all of these remedies with relief to the inflamed parts. In only one case has his eyelids been swollen shut when he was a little boy not fully conscious of the virulency of the plants near which he played.

Desensitization.—Recently Schamberg, a Philadelphia physician has discovered a means of desensitizing persons against ivy poison. The method of treatment which he has devised is to administer the medicine in half a glass of water after meals. The formula is Tincture of Rhus toxicodendron 1 cc., rectified spirit 5 cc. and syrup or elixir of orange 100 c.c. and it is used as follows:

Breakfast, drops	Lunch, drops	Dinner, drops
1	2	3
4	5	6
7	8	9
10	11	12
13	14	15
16	17	18
19	20	21

Immunity established after one months administration will persist for about a month afterward. The same mixture exerts a favorable influence when given as a prevention and in abbreviating the duration of the attack.

Destruction.—The destruction of the poison ivy, which owes its widespread distribution to crows, can be accomplished by the applications of arsenate of soda at the rate of one half to one pound to five gallons of water is effective, but several applications are necessary. A solution containing one pound of white arsenic and two pounds of sal soda in five gallons of water may be used with similar results. Sulphate of iron one hundred pounds to a barrel of water has been found useful. Covering the poison ivy with tar paper creosoted below is effective, according to Dr. G. E. Stone.

Bibliography

ANON.: Ivy Poisoning. The Youth's Companion, Sept. 12, 1918, p. 466.

BLANKINSHIP, J. W.: The Loco and Some Other Poisonous Plants in Montana. Bulletin 45, Montana Experimental Station, 1903.

CHESTNUT, V. K.: Some Common Poisonous Plants. Year Book of the U. S. Department of Agriculture, 1896; 137–146, 1908; Principal Poisonous Plants of the

United States. Bulletin 20, Division of Botany, U. S. Department of Agriculture, 1898; Thirty Poisonous Plants of the United States. Farmers' Bulletin 86, U. S. Department of Agriculture, 1898.

CHESTNUT, V. K. and WILCOX, E. V.: Stock-poisoning Plants of Montana. Bulletin 26, U. S. Department of Agriculture, 1901.

CRAWFORD, ALBERT C.: Laboratory Work on Loco-weed Investigations. Bulletin 121, Bureau of Plant Industry, U. S. Department of Agriculture, 1908.

CRAWFORD, ALBERT C.: Barium, a Cause of the Loco-weed Disease. Bulletin 129, Bureau of Plant Industry, U. S. Department of Agriculture, 1908.

HALL, HARVEY M. and GATES, HARRY S.: Stock Poisoning Plants of California. Bulletin 249, University of California, College of Agriculture, Agricultural Experiment Station, 1915.

HARSHBERGER, JOHN W.: When is Rhus toxicodendron Most Active. Garden & Forest, 8, 239, 1895.

LERRIGO, CHARLES H.: The Poison-ivy Victim, Methods of Cure, Prevention and Immunization. The Country Gentleman, May 2, 1914, page 905.

LONG, HAROLD C.: Plants Poisonous to Live Stock. Cambridge at the University Press, 1917.

MARSH, C. DWIGHT, ALSBERG, C. L. and BLACK, O. F.: The Relation of Barium to the Loco-weed Disease. Bulletin 246, Bureau of Plant Industry, U. S. Department of Agriculture, 1912.

MARSH, C. D., CLAWSON, A. B. and MARSH, HADLEIGH: Lupines as Poisonous Plants. Bulletin 405, U. S. Department of Agriculture, Professional Paper, December 5, 1916.

MARSH, C. DWIGHT: The Loco-weed Disease of the Plains. Bulletin 112, Bureau of Animal Industry, 1909.

MARSH, C. D.: Results of Loco-weed Investigation in the Field. Bulletin 121, Bureau of Plant Industry, U. S. Department of Agriculture, 1908.

MARSH, C. D.: The Loco-weed Disease. Farmers' Bulletin 380 (1909) and 1054 (1919), U. S. Department of Agriculture, 1919.

MOHLER, JOHN R.: Cerebrospinal Meningitis ("Forage Poisoning"). Bulletin 65, U. S. Department of Agriculture, Feb. 14, 1914.

ANON.: The Poisonous Bark of Black Locust Tree. Nature, 103, 132, April 17, 1919; TASAKI, B. and TANAKA, U.: Journal of the College of Agriculture, University of Tokyo, III, No. 5, 337.

PAMMEL, L. H.: Manual of Poisonous Plants, Part 2, 1911.

SCHAMBERG, JAY FRANK: Desensitization of Persons Against Ivy Poison. Journal American Medical Assoc., 73, 1213, Oct. 18, 1919.

STABLER, HARRY SNOWDEN: A Poison-ivy Remedy, the Touch-Me-Not Weed as a Cure. The Country Gentleman, September 19, 1914, page 1573.

STONE, GEORGE E.: Poison Ivy (*Rhus toxicodendron* L.). Nature Leaflet No. 9, Fourth Edition Revised, State Board of Agriculture, Massachusetts, June 3, 1915.

LABORATORY WORK

Suggestion to Teachers.—A supply of the plants described in this chapter should be kept in the dried state for distribution to the class. Some of the material (such as the flowers) may be kept in alcohol. Sections of the stems of one or two of the spurges should be kept in alcohol. European teachers can make selections of European plants mentioned in this chapter. The loco-weeds are found on the great plains and the rattlebox in the east, etc.

Laboratory Exercises

1. Describe the dried plant given you in all of its parts. The study of the flowers may be facilitated by the use of fresh or alcoholic material. This will emphasize the structure of the papilionaceous and euphorbiaceous flowers.

2. Stain mount and study the longitudinal section of the stem of some spurge, as *Euphorbia splendens*, to see the distribution and contents of the latex tubes. Other species of Euphorbia occurring in Europe and elsewhere may be substituted for this one.

3. Examine and draw the seeds of the castor-oil, *Ricinus communis*. Draw the young seedlings previously started by the teacher by planting the seeds in sand, or sphagnum moss. Study the developmental stages of the same.

CHAPTER 8

MISCELLANEOUS DICOTYLEDONOUS PLANTS

St. John's Wort (*Hypericum perforatum*).—This is a perennial, much-branched herb with sessile, elliptical leaves having punctate oil glands with a few purple-spotted ones. The yellow flowers are found in cymose clusters. The stamens are numerous, but arranged in five clusters (pentadelphous).

Symptoms.—White-skinned cattle and sheep eating St. John's wort show an acute inflammation of the white skin, although dark skin remains unchanged. An entire herd of Holstein cattle has been seen with all the white skin hanging in sheets, while the black skin remained intact. The ears at times in sheep are greatly swollen, and if the eyes are effected total and permanent blindness may develop. If the animal is entirely white death may follow, as with extensive burns, the inflammation extending over three-fourths of the skin area. This plant is a decided hindrance to grazing in the French colonies of northern Africa, as in Tunis. Exposure to sunlight is necessary to the development of the curious symptoms of the disease, and animals rapidly recover, if they are protected from the direct rays of the sun, for it appears, as if the herb sensitizes the skin to the invisible chemical rays (the ultra violet) of the solar spectrum. Deaths of horses poisoned by this plant have been reported at Norwood, Maryland within a few years. As the herb preserves all its activities when dried, it may cause trouble, if fed in hay to horses. The treatment consists in blackening the white skin with a mixture of charcoal, linseed oil and lime water. This is applied with a brush and the animals are kept from sunlight and from eating St. John's wort. Cows pastured in a field with this plant, if white-nosed animals, have their udders crowded with eruptions due to contact with the St. John's wort especially on dewy mornings.

The symptoms other than those reported above are dullness, a sinking of the head, loss of appetite, slackening of the pulse and respiration, dilation of the pupils, defective sight and purple lips.

Poisonous Principle.—The oil, which is responsible for the poisoning of the animals, is located in little glandular areas which give the leaf a perforated appearance, when the leaf is held between the eye and the light. The purple coloring matter in the terminal glands has been isolated and named hypericum red. This dye is fluorescent in solution and much resembles certain aniline derivatives.

English Ivy (*Hedera helix*).—This climbing plant makes the ascent of tree trunks, stone and brick walls by means of short, aerial roots. Its leaves are lobed, dark, lustrous, evergreen. The plant is not known to be poisonous to stock, but children have been poisoned by eating the berries.

The plant contains a bitter principle with cathartic, emetic and purgative properties. A poisonous glucoside hederin ($C_{64}H_{104}O_{19}$) and a resin is found in the English ivy. The symptoms produced in children were diarrhœa, nervous symptoms resembling those of intoxication, excitement at first, then coma, convulsions, uncertain gait, stertorous respiration and paralysis.

FIG. 35.—Water hemlock (*Cicuta occidentalis*). One-half natural size. (*After Hall, Harvey M. and Gates, Harry S.: Stock Poisoning Plants of California Agricultural Experiment Station*, 1915, *p.* 223.)

Water Hemlock, Oregon Hemlock and European Hemlock (*Cicuta maculata*, *C. vagans* and *C. virosa*).

Description.—These plants of the family UMBELLIFERÆ (APIACEÆ) are also known as cowbane, musquash root, muskrat weed. The American cowbane, *Cicuta maculata*, has tuberous rootstocks from which arise in swampy situations a stem one to two meters tall bearing twice to thrice compound leaves. The leaf segments are lanceolate, or ellyptic-lanceolate, acuminate, coarsely serrate. The flowers are white borne in compound umbels subtended by linear-subulate bracts. This species ranges from New Brunswick to Manitoba to Virginia and Texas. The western species, *Cicuta vagans*, is found about lakes, in wet meadows and swamps from British Columbia, Montana, Idaho to California. Besides *Cicuta virosa*, the European species, and the above-mentioned, the following species of *Cicuta* have been reported as poisonous: *C. bulbifera*, *C. Bolanderi*, *C. occidentalis* (Fig. 35), *C. californica*, *C. Curtisii*, *C. Douglasii*, *C. purpurea*, and *C. tenuifolia*.

Cases and Symptoms.—The number of cases of cowbane poisoning in Europe has been large. In this country also, especially in the East, the number of cases reported by physicians has been considerable. The writer's personal acquaintance with poisoning by the cowbane of the eastern states, *Cicuta maculata*, began with the receipt of specimens of rhizome received from Dr. G. A. Ricketts of Smithmill, Pa., on April 2, 1912. Excerpts from his letter of March 31, 1912 are here given. "Yesterday, March 30 (11 to 12 M.) Chester Mulhollen, aged 8, Willard Mulhollen, aged 10 and Harold Fun aged 9 mistook these tubers for artichokes. They ate of them for about half an hour, consuming I suppose about as much as I mail to you. All three became suddenly ill a few minutes after they stopped eating. Chester M. started toward the house about 100 feet distant and fell in the door in a convulsion, never regaining consciousness. Harold F. dropped where he was in convulsions. Willard M. became ill a few minutes later, and acted exactly like the others. The neighbors induced vomiting in the two latter, but were unable to force Chester to swallow. He did not vomit at any time. Chester died at 3 P. M. The other two are recovering rapidly. Today both are able to walk about, and have no pain. I did not reach the scene until two hours after the convulsions began. The boys were totally unconscious and do not remember anything that happened after becoming ill. Their pupils were widely dilated, the iris hardly visible. They had a slow weak pulse, 30 to 50 per minute. Vomiting was induced. No purging occurred. The facial muscles contracted rapidly. Their eyelids would almost snap with eyeballs protruding. Eyes turned inwardly. Extreme cyanosis during the spasms. Jaws set so that it was almost impossible to force the mouth open at any time. Convulsions almost continuous, both tonic and clonic. All the muscles were rigid. The poisoning resembled that of strychnin to some extent. Convulsions ceased in Willard and Harold about half an hour after becoming ill. Women of the neighborhood gave ipecac with milk and eggs before vomiting began. Chester's spasms never ceased until death. Please let me hear from you at your earliest convenience. I hope that you can identify the plant and inform me the kind of poison it contains." An account of this case was published in the daily press, but a full account, somewhat incorrect, appeared in the Lancaster Intelligencer under date of May 13, 1912, with the heading "A Death Dealing Plant. Warning to Woodland Wanderers by the State Health Department." The loss of stock by Cicuta poisoning has been considerable in the United States, although the data is inaccurate and incomplete. One man in Oregon, presumably estimating the loss in his immediate neighborhood, makes it 10 per cent. Slade, 1903, estimates a loss of a hundred cattle a year in Oregon. Chestnut and Wilcox, 1901, say that in 1900 in Montana 30 head of cattle and 80 head of sheep were lost.

Poisonous Principles.—If one cuts open the rootstock of any of the species of *Cicuta* drops of an aromatic oil exude, and they impart a peculiar odor to the plant. The poisonous principle is not the oil, but a resin, which has been isolated as cicutoxin. It has been studied by Boehm (1875–76), Wikzemski (1875) and Pohl (1894). It has been found to have properties similar to picrotoxin and with these two toxicologists usually group coriamyrtin, oenanthotoxin and santonin. This poisonous principle, according to Kunkel (1901), is a clear, brown, sticky resin with an acid reaction and which does not harden when dried. It is soluble in alcohol, chloroform, ether and dilute alkalis and is precipitated by acids from alkaline solutions. Injected subcutaneously, by Wikzemski in 1875 into frogs, it produced clonic-toxic convulsions of the whole body, and in doses of 4 to 6 milligrams of the ether extract, it killed the frogs with paralysis. The action of the poison is limited to the central nervous system, that of the heart and organs of respiration are influenced secondarily. The principal effect of cicutoxin is upon the "convulsion center" at the end of the medulla oblongata. The upper part of the brain is not affected, while the terminal paralysis of the spinal cord results from the complete exhaustion following the convulsions.

Although the rootstocks are perhaps the most virulent parts of the plant, yet, the leaves stems and basal parts or the plant contain sufficient poison, especially in the early stages of growth, to produce death. The plant is probably most poisonous in the spring, when the Mulhollen boys were poisoned. Where the soil has been puddled by the trampling of cattle in the swamps, where the cowbane grows, the resin is evidently freed into the pools of water, which if taken by the animal to relieve thirst produces poisoning. Gadd as early as 1774 related in some detail a case of poisoning of cattle from drinking water in which were Cicuta roots.

Remedies. The older authors noticed that if the eating of cowbane was followed by vomiting the patient usually recovered (see ante). The logical remedy, therefore, is an emetic. When the convulsions are violent some opiate should be administered. Chestnut and Wilcox recommended hypodermic injections of morphin to control the convulsions, giving sheep 1½ grams and cattle and horses 3 to 10 grams. A purgative would doubtless help to rid the system of the poison.

Poison Hemlock (*Conium maculatum*).—The poison hemlock is the classical poisonous plant naturalized from Europe into America, where it ranges in waste places from Canada to Indiana, California, Utah and Mexico. It is an erect, much-branched herb, 6–15 decimeters tall. Its lower and basal leaves are petioled, while its upper are usually sessile. All of the leaves are pinnately dissected into ovate leaflets with dentate margin. The umbels are broad with white flowers. Its fruit is 3 mm. long and 2 mm. wide with its ribs very prominent when dry.

Poisons.—The plant is very poisonous containing an alkaloid coniin ($C_8H_{17}N$), which is volatile in vapor of alcohol, or water, and somewhat volatile at ordinary temperatures. It has an alkaline reaction and a burning taste and causes dilation of the pupil. Two other principal alkaloids have been isolated: Conicein ($C_8H_{15}N$) said to be eighteen times more poisonous than coniin and conhydrin ($C_8H_{17}NO$). Fresh leaves contain 0.095 per cent. of coniin and the ripe seed 0.7 per cent.

Symptoms.—The symptoms in man are due to a general and gradual weakening of the muscular power. The power of sight is often lost, but the mind, as in the case of Socrates quoted below, remains clear until death ensues, as it does from the gradual paralysis of the lungs. There are no convulsions. Many domestic animals have been killed by eating the plant. The symptoms for cows being the loss of appetite, salivation, bloating, much bodily pain, loss of muscular power, and rapid, feeble pulse.

Socrates and the Plant.—As the death of the ancient Greek philosopher Socrates is usually associated with this plant the following account is of interest. The form of the indictment of Socrates was as follows: Meletus, the son of Meletus, of the deme Pitthis, on his oath brings the following accusation against Socrates, the son of Sophioniscus of the deme Alopece. Socrates commits a crime by not believing in the gods of the city and by introducing other new divinities. He also commits a crime by corrupting the youth. Penalty, death. He is condemned by a vote of 281 to 220.

The following account of the drinking of decoction of the poison hemlock and the last conversations of the philosopher with his friends is taken from the last part of the Phaedo.

Then Crito made a sign to his slave, who was standing by, and the slave went out, and after some delay returned with the man who was to give the poison, carrying it prepared in a cup. When Socrates saw him, he asked, "You understand these things, my good sir, what have I to do?" "You have only to drink this," he replied, and "to walk about until your legs feel heavy, and then lie down, and it will act of itself." With that he handed the cup to Socrates, who took it quite cheerfully. Socrates, without trembling, and without any change of color of feature, looked up at the man with that fixed glance of his and asked, "what say you to making a libation from this draught? May I, or not?" "We only prepare so much as we think sufficient, Socrates," he answered. "I understand said Socrates. But I suppose that I may, and must, pray to the Gods that my journey hence may be prosperous: that is my prayer be it so." With these words he put the cup to his lips and drank the poison quite lively and cheerfully. Till then most of us had been able to control our grief fairly well; but when we saw him drinking, and then the poison finished, we could do so no longer: my tears came first in spite of myself, and I covered my face and wept for myself: it was not for him, but at my own misfortune in losing such a friend. Even before that Crito had been unable to restrain his tears and had gone away; and Apollodorus, who had never once ceased weeping the whole time, burst into a loud cry, and made us one and all break down by his sobbing, and grief, except only Socrates himself, "what are you doing, my friends"? he exclaimed. "I sent away the women chiefly in order that they might not offend in this way; for I have heard that a man should die in silence. So calm yourselves and bear up." When we heard that, we were ashamed, and we ceased from weeping. But he walked about, until he said that his legs were getting heavy, and then he lay down on his back, as he was told. And the man who gave the poison began to examine his feet and legs, from time to time: than he pressed his foot hard, and asked if there was any feeling in it; and Socrates said, "No:" and then his legs, and so higher and higher, and showed us that he was cold and stiff. And Socrates felt himself, and said that when it came to his heart, he should be gone. He was already growing cold about the groin, when he uncovered his face, which had been covered, and spoke for the last time. "Crito, he said, I owe a cock to Asclepius: do not forget to pay it." "It shall be done," replied Crito. "Is there anything else that you wish?" He made no answer to this question; but after a short interval there was a movement, and the man uncovered him, and his eyes were fixed. Then Crito closed his mouth and his eyes.

"Such was the end, Eshrecrates, of our friend, a man, I think, who was the wisest and justest, and the best man that I have ever known."

FIG. 36.—Fruiting branch of sheep laurel (*Kalmia angustifolia*) collected at Mays Landing, N. J., January 2, 1920. Successive whorls of fruits are shown of different ages.

Ericaceæ.—This family includes a number of shrubs and under shrubs which are poisonous to stock. As they contain essentially the same poisonous principles, although belonging to different genera, they are described botanically first and cases of poisoning are cited afterwards. The general symptoms and the nature of the toxic principles are discussed also.

Lamb Kill, Sheep-Laurel (*Kalmia angustifolia*). This is an underbush growing 18 inches to 2 feet tall with opposite, or whorled, leaves, dark-green above, light-green beneath. The flowers are purple, or crimson, in umbels and the capsular fruit is persistent in whorls on the stems for a number of years (Fig. 36). The sheep-laurel is found in dry woods, or in wet soil from Newfoundland to Hudson Bay, south to Georgia and Michigan. It is common in the pine barrens of New Jersey and on the barren soils of the Pocono plateau of Pennsylvania.

The leaves of this plant are said to be poisonous to sheep and calves, and cases of men being poisoned by eating the flesh of partridges which had fed on the buds and fruits have been reported. There is a general belief among farmers that the leaves of this plant are poisonous to lambs and sheep, hence the common names, but direct evidence is lacking for this plant which we have for the broad-leaved species.

Calico-bush, Mountain-laurel (*Kalmia latifolia*). This is a shrub growing 4 to 8 feet tall and with broad, evergreen, dark-green, lustrous leaves and a large umbel of white, pink, or rose-pink flowers with ten

FIG. 37.—Mountain laurel (*Kalmia latifolia*). (*After The Storrs and Harrison Co. (Painesville, Ohio) Catalogue*, 1913.)

explosive stamens placed in pockets of the cup-shaped corolla (Fig. 37). The fruit is a persistent small capsule (Fig. 38).

Many cattle and sheep are poisoned annually by eating the leaves and tops of this shrub. On Nov. 13, 1918, the writer was taken by Dr. F. Boerner to see a herd of heifers on the Percival Roberts farm at Narberth, Penna., which had been poisoned by eating the leaves of this plant growing in a piece of woodland into which the heifers had been turned to browse and which was usually closed to the feeding of cattle. All of the heifers in the herd were poisoned, but when the writer visited it, all of the animals, but two, had partly recovered through the care of the veterinarian in charge, Dr. D. S. Deubler. The two heifers, which were still suffering from the poison walked about with unsteady gait, they hung their heads low and showed a general lack of activity with considerable frothing at the mouth. All the animals of this herd recovered.

Another case was of a number of educated or trained goats exhibited during Christmas week in the Philadelphia Dime Museum, the stage of

FIG. 38.—Fruiting branch of laurel (*Kalmia latifolia*) collected at Mays Landing, N. J., January 2, 1920.

which was decorated with festoons of laurel leaves. Between the performances the goats roamed over the stage and behind the scenes partaking very freely of the attractive, green laurel foliage. Dr. C. J. Marshall, then out-surgeon of the Veterinary Hospital of the University of Pennsylvania, was called on the evening of December 24, 1894 to see the goats. Six of them died in the Veterinary Hospital from the effects of the laurel poison. Horses have died from eating the leaves, and in May 1895, a monkey was killed at the National Zoological Park at Washington, D. C. by eating a few flowers and leaves offered to it by a visitor. The honey made from the flowers of the mountain-laurel by bees is said to be poisonous. Cases of poisoning may be expected, therefore, from time to time in the region where this shrub grows which is from Canada to Maine and the Allegheny mountains through West Florida, Ohio, Kentucky and

Tennessee. It is common on hill slopes in the Piedmont region west of Philadelphia and in the pine barrens of New Jersey.

Stagger-bush (*Lyonia* (*Andromeda*) *mariana*).—A glabrous shrub growing about two feet tall with deciduous, oblong, or oval leaves. The flowers are white, or cream-colored, urn-shaped and produced in nodding fascicles before the leaves are fully developed. The capsules are grayish and persistent for some time. The stagger-bush occurs in low grounds from Rhode Island to Florida, Tennessee and Arkansas. Sheep have been poisoned and killed by eating the tops and foliage of this plant, which gets its name, because of the intoxicatiom of sheep and cattle by eating it.

Rose Bay, or Great Laurel (*Rhododendron maximum*).—The great laurel is a tall shrub, or small tree forming thickets in the hilly and mountainous parts of the eastern United States from Maine to Ohio and south along the mountains to Georgia. It has large evergreen leaves which being sensitive to cold below 20°F. turn down and incurl during the coldest days of winter. The flowers are large, bell shaped, produced in short racemes from scaly large winter flower buds. This species and several other species, as *R. californicum R. catawbiense*, are poisonous to stock. Cases of death of goats in the Himalaya mountains of India are recorded from eating the leaves of *Rhododendron cinnabarinum*.

General Considerations.—All of the above described ericaceous plants contain the substance andromedotoxin $C_{31}H_{50}O_{10}$, a bitter glucoside more poisonous than aconitin, and more emetic than emetin. It is a narcotic poison.

In the case of goats the symptoms are intense pain, diarrhoea, discomfort, gritting of the teeth, salivation and frequently vomiting, while there is trembling, spasms, vertigo, loss of power and death. Lander and others report somewhat similar symptoms in cattle that have eaten freely of any of the above shrubs.

Chinese Primrose (*Primula obconica*).—This plant is a native of China, but is cultivated in greenhouses and out of doors in summer in this country and Europe. Its leaves are all radical and cordate and covered with glandular hairs. The flowers are borne in umbels at the top of a slender scape 6–12 inches long. The glandular hairs form a drop of poison containing embelia acid, $C_7H_3O_2(OH)_2C_{11}H_{23}$, which is an irritant causing eruptions on the skin of susceptible persons, similar to those produced by poison ivy. The susceptible persons suffer from an eczematous inflammation of the hands and face, and apparently there is a recurrence of the inflammation after some time. Mr. Thomas Meehan describes a person, who after potting a lot of *Primula obconica* had his face so swollen that he remained completely blind for a day.

Privet (*Ligustrum vulgare*).—The privet and several other species of *Ligustrum* are used commonly as hedge plants, for which purpose they are very suitable. The oval leaves are opposite and remain green well into the winter. Cases of poisoning of children, who have eaten the fruits, are recorded causing violent purging, a boy and a girl having died. Horses are poisoned and killed, the symptoms being a loss of power in the hind limbs with a weak and reduced pulse and a temperature of 102°F. The mucous membranes are injected, slightly, the pupils are dilated and death results in 36 to 48 hours.

The poisonous principles are the glucosides ligustrin and ligustron together with syringin $C_{17}H_{24}O_9$ and the bitter glucosidal principle syringopicrin, $C_{26}H_{24}O_{17}$. These also occur in the lilac, *Syringa vulgaris*.

Bibliography

Anon.: Poisoning by Primroses. Scientific American, Supplement 83: 411, June 30, 1917.

Chestnut, V. K.: Thirty Poisonous Plants. Farmers' Bulletin 86, U. S. Department of Agriculture, 1898, pages 23–29.

Crawford, Albert C.: Mountain Laurel, a Poisonous Plant. Bulletin 121, Part II, Bureau of Plant Industry, U. S. Department of Agriculture, 1908.

Harshberger, John W.: Poisonous Plants. Standard Cyclopedia of Horticulture, second edition, vi, 2728–2729.

Long, Harold C.: Plants Poisonous to Live Stock. Cambridge at the University Press, 1917, pages 36–42, 46–49.

Lutz, O.: Poisonous Nature of the Stinging Hairs of Jatropha urens. Science News, 40, 609.

Marsh, C. Dwight: Menziesia, a New Stock-poisoning Plant of the Northwestern States. Drug and Poisonous Plant Investigations. U. S. Department of Agriculture, Bureau of Plant Industry, Preliminary Notice, June 10, 1914.

Marsh, C. Dwight, Clawson, A. B. and Marsh, Hadleigh: Cicuta or Water Hemlock. Bulletin 69, U. S. Department of Agriculture, March 28, 1914.

Nestler, A.: Plants Venomous to Touch. Scientific American Supplement 75: 68, February 1, 1913.

Pammel, L. H.: Manual of Poisonous Plants. Part 2, 1911, pages 645–679.

Laboratory Work

1. The class should describe by use of the outline given on page 54 the various plants described in this chapter, either as alcoholic, dried, or fresh specimens. With

selections and substitutions of plants, the contents of this chapter are of world-wide applicability.

2. The members of the class in botany should make the test for coniin as follows: Concentrated sulphuric acid colors coniin blood-red, the color gradually changing to green. Potassium-cadmium iodide causes an amorphous precipitate of coniin, which distinguishes the latter from nicotin, yielding a crystalline precipitate.

3. Study of sublimable principles. See for details KRAEMER, HENRY: Applied and Economic Botany, 1914: 173–176 Quite a number of plant principles are capable of being sublimed. Not only is this true, when they are in the pure state, but also when they are associated with other compounds in the plant cell. This fact is of interest in the examination of poisonous plants. The procedure is simple, and a small quantity of material (0.020 to 0.050 gram) is required. In the study of flowers, a small piece 10 square millimeters is all that is required. The material is dried, and hence, the usefulness of the dried plants for laboratory study. The dried material is cut up, or comminuted and placed in a small watch crystal, which is covered with a slide, or another watch crystal, for the deposition of the sublimate. The watch crystal containing the material is carefully heated on a sand bath, or on a bath containing sulphuric acid. The method is peculiarly suited for the study of the principles in the ericaceous plants. Tunman (Berichte der Deutsche Pharmaceutische Gesellschaft, 1911, 312) examined some of the Ericaceæ by the microsublimation method and found that they contained arbutin. The latter is a widely distributed glucoside in the family and yields upon treatment with solutions of emulsin, or hydrochloric acid, the sublimable principle hydrochinon. The latter forms prisms and plates and may be examined further with acetone solution, dilute solutions of ferric chloride and water. Arbutin occurs in the leaves of *Arctostaphylos Uva-ursi*, *Vaccinium myrtillus*, *Kalmia angustifolia* (see ante), *Pyrola rotundifolia* and species of *Rhododendron.* This method can be used for the study of the sublimable principles in stramonium, podophyllin.

CHAPTER 9

PRINCIPALLY SOLANACEOUS AND COMPOSITOUS PLANTS

Oleander (*Nerium oleander*).—The oleander is an old fashioned shrub grown in tubs inside of houses in north temperate regions, but in the open in the southern and southwestern United States, in southern Europe and in the Bermuda islands, where it is a mass of color during the month of June and even later in July. It is a native of the Mediterranean countries of Europe also in Persia, Japan and the East Indies. The writer has noticed three varieties in Bermuda, the white-flowered, the pink-flowered and the rose-red variety. The leaves are lanceolate, leathery with the stomata depressed in pits protected by hairs on their under surface.

Cases and Symptoms.—Five soldiers were poisoned by stirring a pot of barley soup with an oleander branch. Vomiting occurred. In one case, there was dizziness and abdominal pain; in another, dulling of the senses and insensibility to external pressure. Three hundred French soldiers in the army corps of Marshal Suchet in Catalonia became sick after eating roasted meat fastened together with skewers made of oleander sticks. A number of these soldiers died. A cow and two goats were poisoned with oleander leaves given with the other feed. The symptoms noted were coldness of the nose and extremities, marked tremors in the posterior extremities and cramp-like contractions of all the muscles. The goats passed into a general paralytic condition and died in about eleven hours, while the cow died paralyzed twenty four hours after eating the leaves. The Arizona Experiment Station records a considerable number of cases of poisoning of horses about Phoenix and in other parts of the state. A fine team of draft horses were lost by eating oleander leaves. Experiments conducted by this station with cows, horses, lambs and mules amply demonstrate the poisonous character of the shrub.

The amount of oleander necessary to cause death in horses ranges from fifteen to twenty grams of green leaves and from fifteen to thirty grams of dry leaves. The fatal dose for cows is from ten to twenty grams of green leaves and fifteen to twenty-five grams of dried leaves. The fatal amount of green or dry leaves for a sheep is one to five grams.

The symptoms, as given in the Arizona bulletin, are increased temperature and pulse, as indicated by the graphs in the experimental portion of the report, dilation of the pupils of the eyes, discoloration of the mouth and nostrils, followed by a sore mouth. The body becomes wet with perspiration, the animal refuses to eat or drink. The fecal discharges are frequent and of a greenish color. The heart is powerfully stimulated and the action of the kidneys is increased slightly and the color of the urine is normal.

Remedies.—There is little or nothing that can be done in cases of oleander poisoning except the administration of an emetic in the case of human beings. Emetics do little good with the lower animals. The physician should combat the human symptoms, as they arise, remembering that oleander poisoning is practically identical with that produced by digitalis.

Active Principles.—Three active principles all of them glucosides reside in oleander. Oleandrin as an amorphous mass showing the characteristics of digitalin is the most important. Neriin and nerianthin are the remaining two and have much less marked poisonous properties.

Whorled Milkweed (*Asclepias verticillata*).—The whorled milk-weed has only lately come into prominence as a poisonous plant in portions of Colorado. The plant has angled stems, narrowly linear leaves in whorls of two to four and greenish flowers tinged with purple of the usual milk weed type. The plant is distributed from Maine to Florida to Texas to Mexico and Arizona. The writer has found it on the Hempstead Plain in western Long Island.

A sheepman near Colona, Colorado lost eighty-five head of lambs which he had turned into his orchard after they were brought down from the range. The only poisonous plant in the orchard was the whorled milkweed. In the fall of 1916, a loss of 750 sheep out of a flock of 1400 was reported from Cortez, Colorado. An examination of the stomach contents was made by the Colorado station which showed that the sheep had eaten practically nothing but milkweed. Grazing on the young plants, as early, as June and throughout the summer months has proved disastrous.

Solanaceæ.—This family contains a number of plants which are celebrated as poisonous plants yielding, however, things of great medicinal importance. The belladonna (*Atropa Belladonna*), is one of the most important drug plants of this family, also poisonous. *Hyoscyamus*, *Scapola*, *Datura*, and *Mandragora* are others.

Thorn Apple (*Datura Stramonium* and *D. Tatula*).—The Jamestown Weed, or Jimson Weed, is a tall, much-branched annual with broadly, ovate, shallowly lobed leaves and single, plaited, trumpet-shaped flowers, either white (*D. Stramonium*) or purple in color (*D. Tatula*). The fruit is a prickly imperfectly, four-celled capsule with sphericidal blackish-brown seeds.

Cases.—The writer's earliest acquaintance with poisonous plants was with this plant and poison ivy. While a lad about twelve years old, three children of the neighborhood were brought into his father's drug store having eaten the seeds of the Jimson weed. They were all suffering from the effects of the poison. Emetics were administered and the writer's father took all three children out into the back yard and compelled them to run about by whipping the calves of their legs with a carriage whip until they broke into a profuse perspiration. He succeeded in saving their lives by this and other heroic treatment. Many cases have been recorded of poisoning by these plants. The Philadelphia Ledger of October 12, 1909 gives this account of poisoning "A verdict of death by accidental poisoning by eating seeds of stramonium, or jimson-weed plant was found by a coroner's jury yesterday in the case of Martha Robinson, 3 years old daughter of Reserve Policeman James Robinson. The testimony showed that Martha and her little friend, Helen Bradley, attracted by the curiously shaped seed pods of the weed growing on a lot at 55th and Paschal Avenue, where they were playing, had broken several of them open and had eaten the seeds. Both children became sick and went home where antidotes were administered to them, but failed to overcome the toxic effects in the case of Martha Robinson, who died in agony. Helen Bradley was apparently on the road to recovery yesterday, but her condition at times was extremely critical."

Symptoms.—The symptoms of poisoning are about the same in all cases. Large doses produce headache, vertigo, nausea, extreme thirst, dry, burning skin and general nervous confusion, with dilated pupils, loss of sight and of voluntary motion, sometimes with many convulsions and death. Smaller doses act like ordinary narcotics. Emetics should be administered and the stomach washed out with tea, tannic acid, or an infusion of oak bark, if in the country. Pilocarpin is recommended by physicians to counteract the drying effect upon the secretions and prolonged artificial respiration must be used to maintain the aeration of the blood.

Poisons.—The thorn apple contains two poisonous alkaloids hyoscyamin ($C_{17}H_{23}O_3N$) and atropin ($C_{17}H_{23}O_3N$) together with scopolamin, or hyoscin ($C_{17}H_{21}O_4N$). The principal substance is hyoscyamin. The true alkaloids together occur to the extent of 0.48 to 3.33 per cent. in the leaves, 0.43 per cent. in the flowers and in the root 0.1 per cent. Daturin was formerly believed to be in the plant, but it has been proved to be a mixture of hyoscyamin and of atropin.

Bittersweet (*Solanum dulcamara*).—The bittersweet is a climbing plant producing purple flowers with rotate corollas followed by a bright-red, ellipsoidal berry. There is considerable divergence of opinion about the poisonous properties of this plant, some denying that the fruit is poisonous. Dr. S. C. Schmucker thinks that the berry fruit is harmless provided the seeds are removed before it is eaten. Perhaps this explains the discrepancies in the statements about the use of the berry as food. However, the plant contains the toxic alkaloid found in other species of *Solanum* and Gillam reports a case of poisoning in sheep and the writer has heard of the poisoning of children on Long Island by eating the fruit. The symptoms as recorded by Gillam in the case of the sheep mentioned above were small, intermittent pulse, temperature 104°F, quickened respiration, staggering gait, dilation of pupils and green bowel discharges. The symptoms seem to be the same in the poisoning of cattle.

Garden Nightshade (*Solanum nigrum*).—The black nightshade is a smooth annual growing one to two feet high with ovate leaves having wavy margins. There are drooping clusters of small, white flowers and black, globose, juicy berries, which ripen from July to October. It is a common introduced weed in rich, shaded grounds and fields east of South Dakota and Arkansas and in damp places westward to the Pacific Ocean.

The amount of poison in this plant varies with the conditions of growth. The plants with the musky odor are the most poisonous. Children have been poisoned by eating the berries, but occasionally owing probably to a variation in the poisonous content of the berries children may eat them with no other ill effect than a pain in the stomach. Chestnut and Wilcox record cases of poisoning in calves, sheep, goats and pigs. The characteristics symptoms are about the same in animals and in man. They are stupefaction, staggering, loss of speech, feeling and consciousness, cramps, and occasionally convulsions. The pupils show dilation. Paralysis is usually the cause of death.

Potato (*Solanum tuberosum*).—Although the potato plant is considered one of the principal food plants of the human race, yet there are parts of the plant which are poisonous, and there are conditions in which the tubers develop poisonous properties. The tops of the plants stems and leaves are poisonous containing the active principle. Even the tubers which are eaten with impunity by the majority of people may be injurious to some persons with a susceptible idiosyncrasy. Again when tubers are stored in a damp cellar to which sunlight has access, they may develop a green color. Such greened tubers and the tubers from which young shoots have sprung develop the poisonous properties of the tops and have been the cause of accidental poisoning. Macfadyen has shown that old sprouted potatoes, even after boiling, are poisonous to horses. Two cows became ill after eating potato parings, as they contain more of the toxic principle than the "flesh."

Poisonous Substances.—The three above mentioned species of the genus *Solanum*, as well, as other species of the genus contain an alkaloid solanin ($C_{52}H_{93}NO_{18}$) having a hot, bitter taste. *Solanum dulcamara* the bittersweet contains in addition dulcamin, which gives it its peculiar bitter-sweet taste. The black night shade contains also solanidin ($C_{40}H_{61}NO_2$) with strong basic properties.

Sneeze-weed (*Helenium autumnale*).—A perennial herb with smooth, or puberulent, stem 6 to 18 decimenters high. The leaves are firm, sharp-pointed with decurrent, sessile bases. The heads are numerous 3–5 centimeters broad borne on long peduncles. The ray flowers are bright-yellow, 3-cleft and drooping, ten to eighteen in number. The disk-flowers are perfect, fertile and yellow in color. The achenes are pubescent on the angles, while the pappus scales are ovate, sharp-pointed, or toothed. The swamp sunflower, or yellow star, is found in swamps and wet meadows from Quebec to Connecticut, Florida, South Dakota, Kansas and Alabama. It occurs in the Rocky mountains from Wyoming to Montana in a variety *grandiflorum*. It is in flower from August until October. Its common name refers to the sneezing of which it produces, a fact known to the Winnebago Indians, who used it for that purpose.

Symptoms.—Sheep, cattle and horses, that are unfamiliar with the plant which is more or less bitter, acrid and pungent, are often poisoned by it when driven to pastures where it is abundant. As a rule, because of the above-mentioned qualities, animals avoid it, but they sometimes acquire a taste for it and are quickly killed by eating it in large amounts.

Little is known about the poisonous principle in the plant, but it apparently is found in largest amount in the flowers. The symptoms, as determined in Mississippi by an observation of calves, are an accelerated pulse, difficult breathing, staggering and extreme sensitiveness to touch. Death is preceded in fatal cases by spasms and convulsions. The spasms in

FIG. 39.—Flowering branch of white snakeroot (*Eupatorium urticæfolium*). (*After Crawford, Albert C.: The Supposed Relationship of White Snakeroot to Milk Sickness, or Trembles. Bull.* 121, *Part* 1, *Bureau of Plant Industry, Plate* 1.)

several cases with sheep are epileptiform, yet a sheep may have such violent convulsions and yet recover without treatment, but they may acquire a mania for it after having been poisoned. The horse and mule succumb to the injurious effects of the toxic substance quicker and more completely than other animals. The influence of the poison appears soon after ingestion and with violence. The horse is unable to control his motions, plunges about blindly, falls dead, or breaks his neck in falling forward with the head under the body. A pint or two of melted lard poured down the animals throat has proved an effective antidote, but it must be administered before the horse loses control of his limbs. The lard probably acts as a local emollient relieving the burning in the throat and stomach and hence allays the violent reflexes.

FIG. 40.—Clump of white snakeroot (*Eupatorium urticaefolium*) in yard of vacant house at 41st and Baltimore Avenue, Philadelphia, October 9, 1919.

Helenium tenuifolium, the fine-leaved sneeze-weed, is often the cause of bitter milk in the south and in the Gulf states. It is fatal to horses and mules.

White Snakeroot (*Eupatorium urticaefolium* = *E. ageratoides*).—The plant has perennial roots and varies in height from one to five feet being more or less branched. The leaves are opposite, ovate, slightly cordate with long pedicles, and are strongly 3-ribbed. The margin is sharply and coarsely serrate (Fig. 39). The heads are small but crowded in dense clusters with a number of white florets to each head. The involucre is narrowly bell-shaped consisting of linear, ovate bracts. The achenes are smooth. This species of *Eupatorium* has been collected in Ontario, Maine, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, District of Columbia, Virginia, West Virginia, Georgia, Louisiana, Michigan, Illinois, Indiana, Minnesota, Iowa, Nebraska Oklahoma and Kentucky (Fig. 40).

Disease.—It is conceded by the latest evidence that this plant is the cause of a disease known as trembles in cattle, or milk sickness in man. The name "tires and slows," employed by Howard (1871), Logan (1849) and Byford (1855), is used in some sections and there are other names, such as swamp sickness, river fever, puking fever, stiff joints, colica trementia, morbeo lacteo, ergodeleteria, gastritis, gastro-enteritis, mukosoma, syro, caconemia and paralysis intestinalis.

Symptoms.—The first sign of the disease in cattle is a listlessness and disinclination to move with muscular weakness and trembling, especially when the animal is driven. Such animals, too, are generally constipated, are greatly excited and are disposed to fight. The characteristic stage of trembling is marked also by stiff joints. The animal may sink to the ground showing great weakness and exhaustion, and may remain on the spot where it has fallen. Animals in this stage may recover, but more often die. Violent exercise causes the dormant poison to become active, and this is especially noticeable when cattle, which have been fattened for market, are driven from the infected localities showing marked trembling, while those that remain at home remain healthy. The breath of such animals has a foul odor described as "garlicky," "like chloroform liniment" and "mildly like acetone," "singularly fetid," "pungent and corrosive."

With sheep the onset of the disease is a loss of appetite and a gritting of the teeth. Such animals are sluggish and manifest a marked disinclination to move. They remain standing in a droopy posture (Fig. 41). Respiration is accelerated, often jerky and somewhat labored. A marked stiffness of the legs and ataxia characterize the movements in walking. This is shown early and becomes aggravated as time passes. If after a day or two the animal is forced to rise and is driven a few yards, muscular spasm, especially in the limbs, is evident. The sheep then refuses to move, stands with hind limbs placed well under the body and all feet spread apart laterally. The back is arched, the neck is stretched and the head lowered (Fig. 42). Quivering then spreads from the limbs over the entire body becoming more intense until it becomes an involitional tremor, followed by slight, intermittent tetanic contractions. At this stage of trembling, ataxia is pronounced and the animal is unable to stand. It drops to the ground with its head and neck outstretched and jaw close to the ground (Fig. 43). Trembling is repeated every time the animal is made to rise. The animal becomes comatose after the second or third day and may lie prostrate on its side until death occurs. The symptoms of trembles in hogs are in general like those in sheep (Figs. 44 and 45).

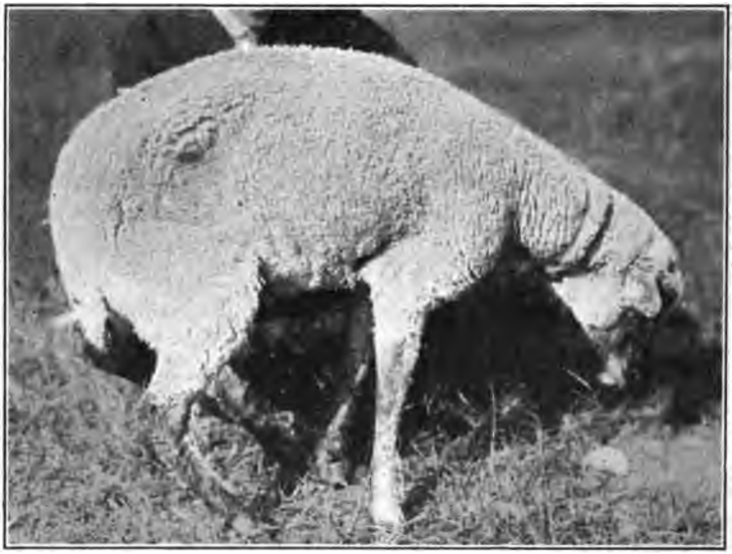


FIG. 41.—Ewe 161 in a characteristic posture when the tremors following the eating of white snakeroot (*Eupatorium urticæfolium*) have become acute. The animal has spread its feet apart to remain standing. (*After Wolf, F. A., Curtis, R. S. and Kaupp, B. F.: A Monograph on Trembles or Milk Sickness and White Snakeroot. Technical Bulletin* 15, *North Carolina Agricultural Experiment Station, July,* 1918, *Plate* 2, *Fig. B.*)

The onset of milk sickness in man is gradual, and after a day or two of weakness and debility accompanied by loss of appetite, the patient is seized with epigastric distress. Violent vomiting follows, associated with obstinate constipation with great thirst. Abdominal pain is noteworthy and muscular tremors are generally present. The foul odor of the breath is characteristic. The tongue is swollen. Respiration is normal, but the temperatures is subnormal (97° to 98°). Severe cases show typhoid symptoms with delirium. Coma precedes death, which may come as

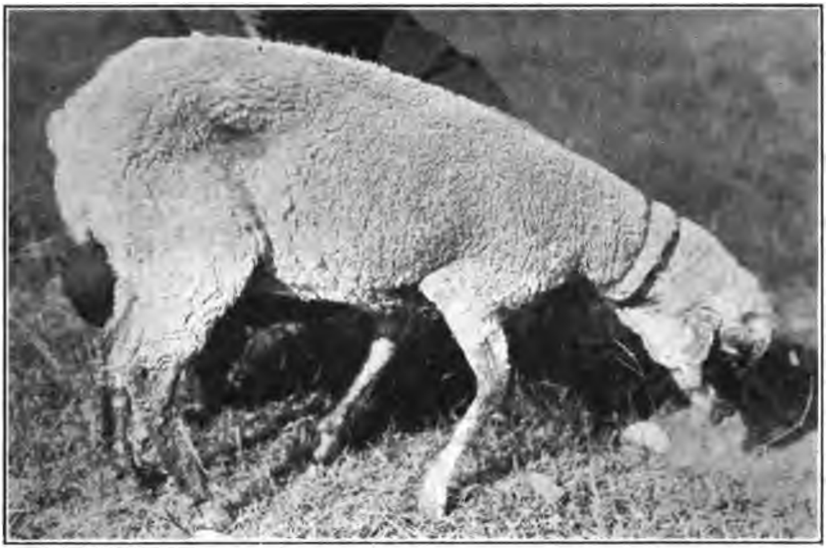


FIG. 42.—Ewe 161 a few seconds subsequent to stage in preceding figure. The animal is beginning to drop down to a resting posture. (*After Wolf, J. A., Curtis, R. S. and Kaupp, B. F.: A Monograph on Trembles or Milk Sickness and White Snakeroot. Technical Bulletin* 15, *North Carolina Agricultural Experiment Station, July,* 1918, *Plate* 3, *Fig. C.*)

FIG. 43.—Ewe 12 in resting posture commonly assumed by affected animals. The same evidences of stupor are present, but the head and neck are extended. (*After Wolf, F. A., Curtis, R. S. and Kaupp, B. F.: A Monograph on Trembles or Milk Sickness and White Snakeroot. Technical Bulletin* 15, *North Carolina Agricultural Experiment Station, July,* 1918, *Plate* 4, *Fig. E.*)

early as two days after the onset of the preliminary symptons. Lasting debility appears to be a common sequel of recovery. The mortality in

FIG. 44.—A pig in which the tremors due to eating white snakeroot have become so violent that the animal has settled backward upon her haunches and is squealing. (*After Wolf, F. A., Curtis, R. S. and Kaupp, B. F.: A Monograph on Trembles or Milk Sickness and White Snakeroot. Technical Bulletin* 15, *North Carolina Agricultural Experiment Station, July*, 1918, *Plate* 6, *Fig. J.*)

FIG. 45.—A pig which has assumed the resting posture from the position shown in the preceding figure. (*After Wolf, F. A., Curtis, R. S. and Kaupp, B. F.: A Monograph on Trembles or Milk Sickness and White Snakeroot. Technical Bulletin* 15, *North Carolina Agricultural Experiment Station, Julv*, 1918. *Plate* 7, *Fig. K.*

men, who have had milk sickness, is approximately 24 per cent. for out of 320 reported cases, 77 persons died. No particular difficulty need be encountered in explaining the excretion of the poisonous principle in the milk for milk acquires tastes and flavors from the feed of animals. The medical practitioner well knows that such substances as opium, morphin and atropin may pass into the mother's milk and act on the nursing child. We have seen how the active principle of mayapple is thus secreted in cow's milk. Notably do organic substances pass into the milk, but many inorganic substances, such as, arsenic, iodine, bismuth, etc., are secreted.

Cause of Disease.—Numerous papers have been written discussing the cause of the disease. These theories may be classified, as follows: (a) mineral poison theory, the ingestion of something from the soil or water; (b) the germ, or microbic theory; (c) the poisonous plant theory. All the weight of evidence is in favor of the latter theory. The experiments have narrowed the poisonous plants down to the white snakeroot, and Mosely (1909) attributed the poisonous action to the presence of aluminum phosphate ($AlPO_4$) in the plant, but experiments with this substance has not substantiated his claims. A synthetic study of the plant has indicated that there are glucosides present in the sap of the white snakeroot, but the particular glucoside responsible for the disease has not been isolated. Further studies on the nature of the active principle are in progress. No efficient remedial treatment has yet been discovered.

Ragwort (*Senecio Jacobœa*).—The writer's first acquaintance with this plant, or Stinking Willy, as it is called in Nova Scotia, was with the receipt of specimens of the plant for identification from a former student, Dr. A. E. Cunningham of Antigonish, Nova Scotia with the statement, that it was the cause of the socalled Pictou cattle disease. Not much was learned about the disease until the receipt of the Annual Report of the Department of Agriculture of New Zealand for 1903 where a full detailed account covering fifty pages is given.

Description.—The tansy ragwort, or staggerwort, is a perennial plant with short, thick rootstocks. The stems are stout, simple, branched above, smooth, or somewhat wooly. The lower leaves are petioled, the upper sessile. The leaf segments are oblong-cuneate, dentate, or incised. The heads are numerous, short-peduncled in large compact corymbs. The involucre is narrowly campanulate with linear-lanceolate, acute bracts. The number of ray florets varies from twelve to fifteen. They are yellow with truncate, dentate apices. The disk florets are brownish-yellow. The plant is found in waste planes in Nova Scotia, New Brunswick and Ontario, and has been found on the ballast about New York and Philadelphia having been introduced from Europe, where it is native.

Disease.—The Pictou cattle-disease is only found in Canada, in a district spread along the northern shore of the Nova Scotia peninsula, a tract of country extending about forty miles along that coast and stretching from five to twelve miles inland. In this district, it has been noted for some forty years, now at one end of the area, now at the other. Cattle are in the main affected, but cases are on record in which sheep and even horses have shown symptoms of the disease. The disease would seem to be very chronic, and all the cattle upon a farm are not affected simultaneously. What appears to be a similar disease has been recorded in Great Britain and in Germany, but the ragwort has not been associated apparently with the disease as its cause.

Symptoms.—The most detailed account of the symptoms come from New Zealand where the disease has occurred in the Southland and in a small portion of the Waikato district, Auckland Province, in the Wairaropa district and probably on the west coast of the South Island. The most notable symptoms in horses are a weak, staggering, swaying gait, when standing a tendency to stamp with one or both hind feet, twitching of the muscles, an amaurotic condition of the pupils, yellowness of the visible mucous membranes, a clammy condition of the mouth, irregular and generally weak intermittent pulse, a depraved appetite and a normal temperature. The earliest noticeable symptom is drowsiness and general dullness. There is a depraved appetite, the horse eating barn yard rubbish. There is inability to completely coordinate the muscles and in advanced stages difficulty to keep from falling. There are symptoms like drunkenness, a staggering, swaying gait followed by a frenzied condition, such as madness, head held high, etc. Soon the animal falls down unable to rise. Later the horse becomes unconscious, complete coma sets in and death rapidly comes.

In dairy cows, the first notable symptom is diminution of the milk supply. Later the milk has the peculiar odor of the animal's skin with an acrid flavor. There is rapid emaciation, a voracious appetite, or a total absence of any desire for food. Jaundice is more or less pronounced. Dropsy of the abdomen is frequently observed, while the animal is alive. There is a similar want of coordination of the muscles, as in horses, and there is always chronic diarrhœa of a most persistent type accompanying the rapid emaciation. Feeding cattle and cows kept for purely breeding purposes, do not exhibit quite the same symptoms. Diarrhœa is not nearly so acute, dropsy of the abdomen is not so evident, and whereas in the dairy cow symptoms may be exhibited for even ten days, or a fortnight, in these cows death occurs in from two to five days, the animal being in a visible state of excitement almost bordering on frenzy. The proof that the milk is changed is the refusal of the calf to come to its mother paying no attention to her bellowing.

Post-Mortem Study.—The most striking appearance on skinning an animal in the post-mortem examination is the yellow, bile-stained condition of the tissues. The peritoneum, the fat, and the general viscera all exhibit the same appearance, which may vary from a faint tinge to the proverbial "yellow as a guinea." In cattle, there is frequently a large accumulation of a semi-gelatinous, yellowish exudate, situated subcutaneously along the inferior borders of the thorax and abdomen. The most marked change is in the liver, which is almost constantly in a state of chronic cirrhosis. The organ is usually smaller than normal, of a dull, mottled, slaty-blue color frequently pitted and almost "hob-nailed," there being occasionally small dark-blue pitted areas underneath the capsule and throughout the structure. The lymphatic glands are usually much enlarged.

Feeding experiments and the fact that the Auckland District in New Zealand, where *Senecio Jacobaea* occurs, is separated by thousands of miles from the Pictou district of Nova Scotia, where the plant is also found, is sufficient proof that the ragwort is the causative agent of the same disease in cattle in both widely separated countries.

Hay-Fever Plants (*Pollinosis*).—Hay-fever, or autumnal catarrh, is an affection of the upper air passages occurring periodically, usually at or near a fixed date in the early autumn, sometimes in the spring, or summer, characterized by its sudden onset and as sudden termination, and by a swelling of the mucous membranes of the nasal and adjacent cavities, irritating discharges therefrom, and various symptoms of coryza, and occasionally by asthmatic paroxysms. It has been conclusively proved by many authorities that hay-fever does not occur unless we have a conjunction of three necessary factors:

1. An external air-borne irritant;
2. A sensitive, or diseased, nasal mucous membrane;
3. An unstable nerve center.

The second and third elements are usually associated with a functional, or hereditary predisposition to the disease. The first is associated with the external causative factor.

The President of the American Hay-Fever Prevention Association states that about one per cent. of the population of the United States suffers from the disease. As he believes that the external cause is the pollen of various plants, the extermination of these plants would result in the practical elimination of hay-fever. Various plants give rise to pollen grains in sufficient number to provide the irritating material cause of hay-fever. Such are the rose, rye, sweet vernal grass (*Anthoxanthum odoratum*) sweet-scented soft grass (*Holcus odoratus*), meadow grass, Indian corn, barley, wheat, oats, bean flowers, lilies, elder bushes in bloom, the goldenrods, hay, timothy, spiny amaranth, marsh elder, yellow dock, Johnson grass and cockle-bur. E. Philip Smith enumerates the principal hay-fever plants. The hay-fever plants par excellence are the common ragweed (*Ambrosia artemisiæfolia*), great ragweed (*Ambrosia trifida*) and western ragweed (*Ambrosia psilostachya*). These plants are widely distributed and blossom in late August and early September, producing an abundance of wind-carried pollen. Perhaps more cases of hay-fever are due to these plants than all others put together.

Common Ragweed (*Ambrosia artemisiæfolia*).—This is a native, annual, branching plant growing about two to three feet tall. It has thin leaves, bipinnately divided and racemes of numerous staminate heads with chaffy receptacle. The pistillate heads are clustered. The plant is found from Nova Scotia to British Columbia, Florida and Mexico.

Great Ragweed (*Ambrosia trifida*).—This is an annual plant with hirsute to hispid stems, 1–5 meters tall, and opposite, deeply three to five lobed leaves with serrate margins. The racemes of staminate heads are 5–15 centimeters long with saucer-shaped involucres, while the pistillate heads are clustered in the axils of the leaf-like bracts. The great ragweed occurs in the rich alluvial soil along streams in moist, meadow soils from Quebec to Northwest Territory, Florida, Arkansas and Colorado. The third species of ragweed, *Ambrosia psilostachya* ranges from Northwest Territory to Illinois, Texas, Mexico and California. *Artemisia heterophylla* of California may also be classed with the hay-fever inducing plants. The results of experimentation with various kinds of pollen have been most discordant. As the digestive power of the nasal mucosa is very slight and the pollen-grain is effectively sealed, it is difficult to understand how any of the protein-contents could diffuse out passively. The affects of the possible germination of pollen in the nasal passages may be set aside. Foreign bodies may produce sneezing, but not the after effects. E. Philip Smith suggests that there is an oily substance on the outer wall (exine) of the pollen grains which cause hay fever. Experimenting with pollen of *Hibiscus*, he found upon shaking it up with cold ether, that an oil could be obtained by allowing the ether to evaporate. This oily residue applied to the skin raised a severe blister. If this idea, that the poisonous principle of pollen is an irritant oil, a new light is thrown upon the nature of the poisoning which resolves itself into a kind of dermatitis, or irritation of the delicate, ciliated epithelium lining the nasal cavities.

Granted that the pollen of these plants is responsible for hay-fever, the way of controlling the disease would be the extermination of the plants. This might be accomplished by hand pulling, if every one would cooperate in this laudable enterprise. Barring the entire destruction of these noxious weeds, mowing just before they start to shed their pollen would be a means of their final destruction, as this would prevent the formation of seeds upon which the perpetuation of the species depends. Concerted action should be taken to exterminate these useless and deleterious ragweeds.

Remedies.—Recent work has been done along remedial lines by securing a hay-fever vaccine to be used in the immunization of the susceptible person. To secure this vaccine, the flowers of the various hay-fever plants are collected when pollination has started. They are dried and the pollen collected by means of fine sieves. The pollen is dried thoroughly and preserved in a dry state until it is to be extracted. In the preparation of the extract.

1. The pollen is mixed with sufficient physiological saline solution (0.85 per cent.) to make a fairly thick paste.

2. The paste is transferred to a ball mill and ground for 24 hours, or, until microscopic examination shows that the pollen grains are broken.

3. Physiological saline solution is added and the resultant mixture is centrifuged to remove insoluble debris.

4. The extracted protein is purified by precipitation with acetone.

5. The precipitate is dried and thus preserved until needed.

6. For use, the precipitate is dissolved in physiological saline solution. The amount of protein-nitrogen in this solution is determined by the Kjeldahl method.

7. The solution is then diluted so that each cubic centimeter will

8

contain certain fractions of a milligram of protein-nitrogen. The lowest dilution, 1 cc. of which may be used as the initial dose in treatment, contains 0.00 25 mg.

8. The final solutions are preserved from contamination by the addition of 0.35 per cent. tricresol and sterilized by filtration. Sterility is determined by careful aerobic and anaerobic cultural tests.

Vaccines.—Two kinds of vaccines have been prepared the "spring" and "fall." The hay-fever vaccine "spring" contains the varieties of pollen which are the causative agents in the great majority of hay-fever cases occurring in the late spring and early summer. The hay-fever vaccine "fall" contains only proteins from the pollens of ragweed, goldenrod and maize. For immunization against hay-fever, the first dose of the vaccine in a syringe should be given 30 days before the expected attack and the vaccine should be used weekly at intervals during the entire period of accustomed attack or until immunity is established.

Another preparation is pollantin, used as an antitoxic serum to secure immunity against an attack of hay fever.

Walnut Pollen as a Cause of Hay Fever.—The spring type of hay fever is very troublesome in the Sacramento Valley, California where it has been found to be due to the pollen of the native Californian black walnut (*Juglans californica, var. Hindsii*), which produces pollen in abundance during the period of the prevalences of the malady, which disappears after the close of the flowering period. Biological tests were made upon eight hay fever subjects with positive results in each case with the use of walnut pollen. Twelve susceptible persons were examined at Chico, where cases are common, and where the walnut is planted as an ornamental tree, and in every case positive reactions were obtained with extracts prepared from the Californian black walnut pollen.

Bibliography

Bond, H. G.: Box Elder Poisoning. The Veterinary Alumni Quarterly, Ohio College Veterinary Medicine, 1916, 111.

Boston Globe: Hay Fever Causes. Health Board puts Blame on Certain Types of Weeds. Boston, Sunday September 3, 1916, page 12.

Clark, George H. and Fletcher, James: Farm Weeds of Canada. Illustrated with Colored Plates, Ottawa, 1906, pages 51, 52, 57.

Cox, Herbert R.: Hay-fever Season is Here. Some Weeds that Make Folks Sneeze. The Country Gentleman, August 5, 1916, page 1467.

CRAWFORD, ALBERT C.: The Supposed Relationship of White Snakeroot to Milk Sickness. Bulletin 121, Part I, Bureau of Plant Industry, U. S. Department of Agriculture, 1908.

DUNBAR, PROF. DR.: Pollantin Specific Remedy for Hay-fever, Autumnal Catarrh, Rose Fever and Similar Complaints.

GLOVER, GEO. H. and RUBBINS, W. W.: Colorado Plants Injurious to Live Stock. Bulletin 211, Agricultural Experiment Station of the Colorado Agricultural College, 1915.

HALL, HARVEY M.: Walnut Pollen as a Cause of Hay Fever. Science new ser., lvii, 516–517, May 24, 1918.

HARRIS, F. W. and COCKBURN, F.: Alleged Poisoning by Potatoes. American Journal of Pharmacy, 90, 722–726, October, 1918.

HILGENDORF, F. W.: Plants Poisonous to Stock. Journal of the Canterbury Agricultural and Pastoral Association, 3d Ser., vi, 15–21, June, 1918.

HOLLOPETER, W. C.: Hay-fever, its Prevention and Cure. Funk & Wagnalls Company, New York, and London, 1916, pages 1–347 with extensive bibliography.

LONG, HAROLD C.: Plants Poisonous to Live Stock. Cambridge at the University Press, 1917, pages 44–46, 50–60.

MARSH, C. DWIGHT: Prevention and Loss of Live Stock from Plant Poisoning. Farmers' Bulletin 720, U. S. Department Agriculture, 1916.

MARSH, C. DWIGHT and CLAWSON, A. B.: Eupatorium uticaefolium as a Poisonous Plant. Journal Agricultural Research, xi, 699–715, Dec. 24, 1917.

MULFORD, H. K., COMPANY: Hay Fever Vaccine for the Prevention and Treatment of "Spring" and "Fall" Hay Fever. Mulford Working Bulletin No. 1, pages 1–8.

ANON.: Hepatic Cirrhosis affecting Horses and Cattle (so called "Winter Disease"). Annual Report of the Department of Agriculture of New Zealand, 1903, Division of Veterinary Science, pages 227–278.

PAMMEL, L. H.: Manual of Poisonous Plants. Part 2, 1911, pages 713–733, 753–802.

SCHEPPEGRILL, D. W.: Hereditary Hay Fever. Scientific American, cxix, 371, iv or 9, 1918.

SMITH, E. PHILIP: Pollinosis ("Hay Fever"). The Journal of Botany, British and Foreign, lviii, 40–44, Feb., 1920.

WILCOX, W. F.: A Sheep-killing Plant. Colorado finds that the Whorled Milkweed is Poisonous. The Country Gentleman, September 6, 1919, page 40.

WILSON, F. W.: Oleander Poisoning of Live Stock. Bulletin 59, University of Arizona, Agricultural Experiment Station, April 15, 1909.

WOLF, F. A., CURTIS, R. S. and KAUPP, B. F.: A Monograph on Trembles or Milk Sickness and White Snakeroot. Technical Bulletin 15, North Carolina Agricultural Experiment Station, July, 1916.

LABORATORY WORK

1. Study and describe the several plants which form the themes for this chapter preserved for the purpose in alcohol, dried or fresh specimens. The botanical teacher with knowledge of his flora can use the facts of this chapter in laboratory work in any part of the civilized world.

2. Test the action of the leaves of Jimson weed, especially if fresh, by rubbing the leaves with the index finger and then rubbing the eye balls with the finger. Does the pupil dilate as a result of such treatment?

3. The following test with hyoscyamin can be made. Hyoscyamin shows an alkaline reaction with phenolptalein and causes a yellow to red precipitate when touched with a 2 per cent. solution of mercuric chloride in diluted alcohol.

4. Examine microscopically and draw the pollen of the ragweeds, *Ambrosia artemisiaefolia* and *Ambrosia trifida*, preserved in weak formalin (2 per cent.) for this purpose, or dried pollen may be substituted, when mounted in water for examination.

CHAPTER 10

FEEDS AND FEEDING

The food of the domestic animals (excluding the carnivorous house pets, the dog and the cat) is vegetable derived from living plants, or from plants cured in various ways for preservation during that part of the year when plant life is dormant. When we discuss the plants suitable as food for cattle, whether fresh or preserved, we are dealing with forage plants. If the cattle are turned into the open fields to eat the food plants found there, they are consuming the pasture plants, usually the pasture, or pasturage. Soilage, used as a term for the first time in 1900, means supplying forage fresh from the field to animals in confinement. The plants, which are grown for this purpose, are known as soiling crops. Fodder is a comprehensive term for cattle food usually fed in bulk and in the dry state,[1] while hay is grass that has been cut and dried for use as fodder. Ensilage, or silage, is the preservation of green forage such, as corn, beet tops, and other plants in a pit dug in the ground, or in a large tank, or vat, above ground known as the silo. By a process of fermentation, the green plant parts are converted into silage. Stover, or corn stover, denotes the dried stalks of corn from which the ears have been removed.

Chemical Constituents.—The substances, which have been formed in the living plant through the activity of its living protoplasm in the leaves of the green plant principally, and have found their way into the plant by the active absorption of the roots, or by a gaseous interchange of oxygen and carbon dioxide with the air, have been classified by chemists into several groups. These are water, ash, or mineral matter, crude protein, fi er, fat, nitrogen-free extract, carbohydrates. Fresh mangels contain 90.6 per cent. of water, 1 per cent. of ash, 1.4 per cent. crude protein, 0.8 per cent. fiber, 6.1 per cent. nitrogen-free extract and 0.1 per cent. fat. Timothy hay shows on analysis, 11.6 per cent. water, 4.9 per cent. ash, 6.2 per cent. crude protein, 29.9 per cent. fiber, 45.0 nitrogen-free extract, 2.5 per cent. of fat, while dent corn has the composition of 10.5 per cent.

[1] Fodder corn is applied to stalks of corn green or dry with all the ears which have been grown primarily for forage.

water, 1.5 per cent. ash, 10.1 per cent. crude protein, 2.0 per cent. fiber, 70.9 per cent. nitrogen free extract and 5.0 per cent. fat.

Nature of Feeds.—In the consideration of feeds, it is important to differentiate between those which have a coarse, bulky character and others which are more concentrated and nutritious. Accordingly the terms "roughage" and "concentrates" are used. Roughage represents the coarser feeding stuffs, which have a considerable amount of fiber and therefore, smaller amount of digestible matter. Roughage is necessary to keep the animal in good condition, as it is an aid to digestion. Concentrates are feeding stuffs of a concentrated nature, which have a small amount of fiber and, therefore, a relatively large amount of digestible matter.

Digestion.—As the bodies of the domestic animals are composed of protein, fat, mineral substances, dry substances and water, these must be supplied in the food which the animal consumes. The changes, which the food undergoes within the digestive tract of the animal to prepare it for absorption and for utilization by the animal bodies are known as digestion. Digestion is accomplished by the enzymes, or ferments, produced by the glands of the mouth stomach, pancreas, the small intestines and the liver. Bacteria found in various paths of the alimentary canal help to break down the food also, especially the fibrous materials. A nutrient is any food constituent, or group of food constituents, that help in the support of animal life. There are three primary classes of nutrients, viz., crude protein, the carbohydrates and the fats. Air, water and mineral matter might also be classed with nutrients, but are usually excluded from this category. When it has been found that the above substances are digested by the domestic animals, they are termed digestible nutrients.

Rations.—A ration on the farm is the feed allowed, or set apart, to support a given animal for a day of 24 hours, whether all of the food is given at one time, or is divided into portions given at intervals throughout the day. There are several kinds of rations recognized in the feeding of animals. A complete or a balanced ration is the feed or combination of food stuffs which will supply the several nutrients, crude protein, carbohydrates and fats in the right amounts, and in the right proportions without excess of any nutrient, so as to nourish a given animal for one day. A maintenance ration is one that furnishes enough, but no more, of each and all of the several nutrients than is required to maintain a given resting animal, so that it will neither gain nor lose in weight.

As the character of the alimentary tract with its associated glands and other organs are considered by the anatomist and as the processes of mastication, the digestion in the simple stomach of the horse and pig and in the three stomachs of the ruminants, and later in the small intestine, by the pancreas, the liver and in the large intestine are discussed by the animal physiologist, they are omitted from description here. It may be said, however, that protein digestion is accomplished by the pepsin in the stomach assisted by the trypsin and erepsin in the small intestine. The digestion of either starch or sugars consists in converting them into glucose, or glucose-like sugars and this transformation takes place through the activity of the ptyalin in the saliva and by the amylase formed in the small intestine, where the final carbohydrate digestion takes place. The fats are digested by the secretions of the pancreas, where a fat splitting enzyme lipase is formed which breaks fats into glycerin and fatty acids. The bile secretions largely made up of alkaline salts react with the fatty acids to form soaps, which with the glycerin is absorbed by the intestinal wall.

Metabolism, or the process by which the digested nutrients of the food are utilized for the production of heat and work, or built up with the living matter of the body, or broken down and eliminated, is a subject for the consideration of the animal physiologist.

Digestibility of Animal Foods.—A large number of experiments have been performed on animals of various kinds in order to ascertain the digestibility of the feeding stuffs. The list of feeds, which have been used in these experiments, is a long one. Out of these experiments a number of important facts have been adduced. The average percentage of each nutrient digested in a feeding stuff is termed the coefficient of digestibility, or digestion coefficient, for that nutrient in the feed. The food is given to the animal by weight and in these trials it is generally assumed that all matter appearing in the feces has escaped the action of the digestive ferments and so represents the indigestible part of the food. Thus for dent corn 90 per cent. of the total dry matter, 74 per cent. of the crude protein, 57 per cent. of the fiber, 94 per cent. of the nitrogen-free extract, and 93 per cent. of the fat is digestible. Feeds with little fiber have high digestibility. To determine the digestible nutrients in any feeding stuff, the total amount of each nutrient in 100 pounds thereof is multiplied by the digestion coefficient for that nutrient. Thus 100 pounds of dent corn contain 10.1 pounds of crude protein of which 74 per cent. is digestible. which indicates that there are approximately 7.5 pounds of digestible protein in 100 pounds of dent corn.

Nutritive Ratios.—As protein serves special uses in the body in discussions of feeds and rations the term nutritive ratio is used to show the proportion of digestible protein contained in comparison with the other nutrients, so that by nutritive ratio is meant the ratio which exists in any given feeding stuff between the digestible crude protein and the combined digestible carbohydrates and fat. The nutritive ratios for dent corn is determined as follows: The digestible fat in 100 pounds of dent corn is 4.6 pounds, which is multiplied by 2.25, because fat will produce 2.25 times as much heat on being burned in the body as do the carbohydrates. Add the product to 67.8 pounds, the digestible carbohydrate, which gives 78.15 and divided by the amount of digestible crude protein 7.5, which gives as a quotient 10.4, which is the second factor of the ratio. The colon is used to express the nutritive ratios thus 1 : 10.4, which is read as follows: for each pound of digestible crude protein in dent corn there are 10.4 pounds of digestible carbohydrates, or fat equivalent. It follows from the above that a narrow nutritive ratio is one having much crude protein in proportion to carbohydrates and fat combined. A wide ratio is where the percentage of crude protein is small compared to the carbohydrates and fats. Linseed meal rich in protein has the narrow ratio of 1 : 1.6; oats 1 : 6.3, while oat straw has the wide ratio of 1 : 44.6, because of its low content of crude digestible protein. Carbonaceous feeds are those with a wide nutritive ratio. Nitrogenous feeds are those with a narrow nutritive ratio.

Energy of Food.—The energy of the animal body is derived from the food which serves as the fuel in supplying that energy. The full value of a feeding stuff is ascertained by burning a weighed quantity of it in pure oxygen gas under pressure in an apparatus called a calorimeter. The evolved heat is taken up by water surrounding the burning chamber and is measured with a thermometer, the units of measurement being the calorie and the therm. A calorie is the amount of heat required to raise the temperature of 1 kilogram of water 1°C. or 1 pound of water nearly 4°F., A. therm is 1,000 Calories, or the amount of heat required to raise 1,000 kilograms of water 1°C. or 1,000 pounds of water nearly 4°F.

The full value of 100 pounds of

Anthracite coal	358.3 Therms
Timothy hay with 15 pc moisture	175.1 Therms
Pure digestible protein	263.1 Therms
Pure digestible carbohydrates	186.0 Therms
Pure digestible fat	422.0 Therms

The available energy is the fuel value of any food after deducting the losses due to the evacuation of undigested food, the fermentations of foods, the excretion of urea and other protein bodies. Besides the energy yielding foods, there are a few substances like the vitamines which in minutely small quantities are necessary for the maintenance of health besides certain mineral substances, such as those which control the life processes.

As a result of the knowledge of feeds and feeding given above, scientists have drawn up tables showing the amount of each class of nutrients, which are known as the feeding standards. Thus, Haecker of the Minnesota Station found that the 1,000-lb. dry, barren cow can be maintained on 0.6 lb. of crude protein, 6 lbs. of carbohydrates and 0.1 lb. of fat, all digestible. A 1,000-lb. milk-producing cow should be allowed 0.7 lb. of crude protein, 7 lbs. of carbohydrates and 0.1 lb. of fat, all digestible. These feeding standards are at variance with the Wolff-Lehmann feeding standards where a cow yielding 22 lbs. of milk requires 29 lbs. of dry matter, 2.5 lbs. of protein, 13 lbs. of carbohydrates, 0.5 lb. of fat. The nutritive ratio is 1:5.7. A horse at medium work, according to the Wolff-Lehmann feeding standard requires 24 lbs. of dry matter, 20. lbs. of crude protein, 11 lbs. of carbohydrates, 0.6 lb. of fat with the nutritive ratio 1:6.2.

Bibliography

Allen, E. W.: The Feeding of Farm Animals. Farmers' Bulletin 22, U. S. Department of Agriculture, 1895.

Armsby, Henry P.: The Maintenance of Rations of Farm Animals. Bulletin 143, Bureau of Animal Industry, 1912.

Gardner, Frank D. with Collaborators: Successful Farming. Ready Reference on all Phases of Agriculture for Farmers of the United States and Canada. The John C. Winston Company, Philadelphia, 1916, pages 562–572.

Hall, A. D.: The Book of Rothamsted Experiments. E. P. Dutton and Company, New York, 1905, pages 240–259.

Henry, W. A. and Morrison, F. B.: Feeds and Feeding. A Handbook for the Student and the Stockman. The Henry-Morrison Company, Madison, Wisconsin, Fifteenth Edition, 1915.

Lusk, Graham: Science of Nutrition. W. B. Saunders Company, 3d edition, 1918.

Laboratory Work

The laboratory period corresponding to this lesson may be devoted to an oral or a written test, which should be given occasionally as a matter of review and to try out the proficiency of the different members of the class.

CHAPTER II

THE STRUCTURE AND GENERAL ECONOMIC IMPORTANCE OF GRASSES

The grass family, *Graminaceæ*, is the most important family economically speaking in the whole vegetable kingdom. It includes several thousand species, all of them with a few exceptions (see ante) being without any deleterious properties. The vegetational associations where grasses control the faces are known as meadows, prairies, pampas, steppes and savannahs.

Habit.—The grass family includes low, erect herbs. A few, such as the bamboos, are shrubs, or trees. Some grasses are creeping, others trailing, semi-erect, erect and unbranched, or very freely branching from the base (Fig. 46). Several, although perennial, are monocarpic, flowering and fruiting but once. In duration grasses are annuals, winter annuals, living through the winter and sending up flower stalks the next spring, or are perennials.

Roots.—Their roots are fibrous, and secondary, that is, there is never at any time a primary root. The roots in such grasses as maize may be divided into the horizontal, feeding roots penetrating the soil at no great depth, the deep roots (3½ feet in corn) for anchorage and the prop roots which develop as aerial roots from the lowermost nodes of the upright stem and later enter the soil bracing the stem during storms of wind. Occasionally, the deep roots draw upon the deep-seated supplies of water, especially in arid countries, where such grasses, as the buffalo grass (*Buchloë*), grow to a depth of seven feet. Ordinarily in the grasses with horizontal underground stems, the roots spring freely from the nodes and from tufts of short spreading character. The interlacement of the subterranean roots and stems is so compact in areas where grasses dominate in herbage, that shrubs and trees are unable to establish themselves in competition with the grasses and this is one of the cogent reasons for the treelessness of prairies and other characteristic grasslands, such as the pampas of South America.

Stems.—The stems of grasses are divided into nodes and internodes and are called culms (halms, haulms). The nodes are usually enlarged always solid joints, while the internodes are hollow (bamboo and most other grasses), or solid (maize and sugar cane). The underground stems, or rootstocks (rhizomes), are likewise jointed and have sometimes, as in the marram grass, a hard, sharp-pointed, growing apex, which enables the rootstock to push its way through the resistant soil. Occasionally, as in the reed *Phragmites communis* of our eastern fenlands, rhizomes are found, as thick, as a fountain pen, and 5.8 meters long, enabling this marsh grass to spread with great rapidity in the occupation of new areas of marshland. Two types of branching of the erect stem have been distinguished. The extravaginal method is where the new lateral branch breaks through the sheaths of the basal leaves of the stem giving rise to horizontal branches. This method of branching is typical of the sod-, or turf-forming grasses, and these alone are suitable in the construction of lawns, croquet grounds and golf courses. The prairies of the middle west owe their closed turf to the presence of

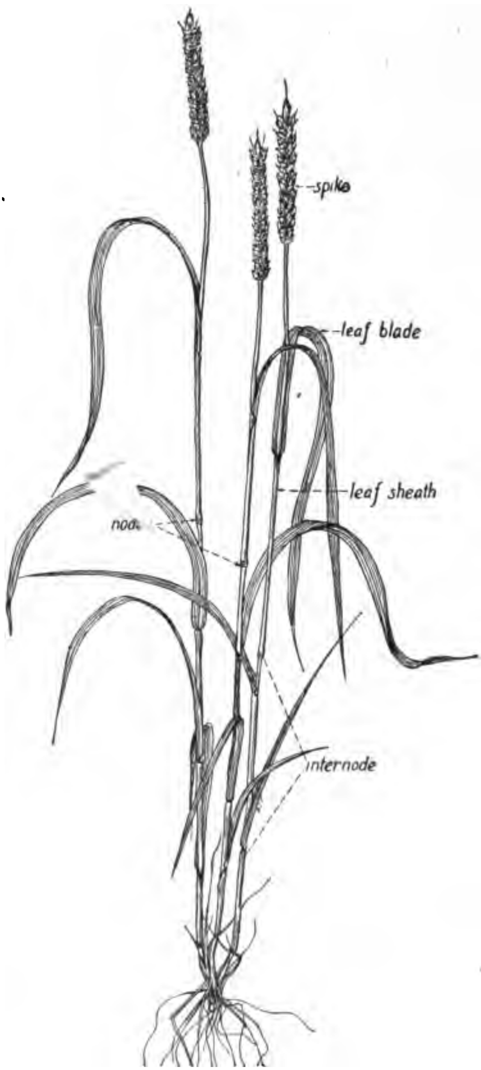


FIG. 46.—Wheat plant showing the general habit of grasses. (*Robbins*.)

grasses of this sort. The second method of branching has been termed the intravaginal where the new branches grow inside of the sheath parallel to the stem, finally breaking out at the top of the sheath. Such grasses are known as bunch, hassock, or tussock grasses and are characteristic of the western plains, or steppes of the world, where the tufts of grasses are separated by intervals of soil bare of grasses. When the stem of grasses, especially agricultural grasses, such as maize, rye and wheat, are prostrated by a wind storm, they are said to be lodged. No mechanical tissue, which the stem may have, will prevent lodging, if the wind be sufficiently strong. Frequently after lodging, the stem will

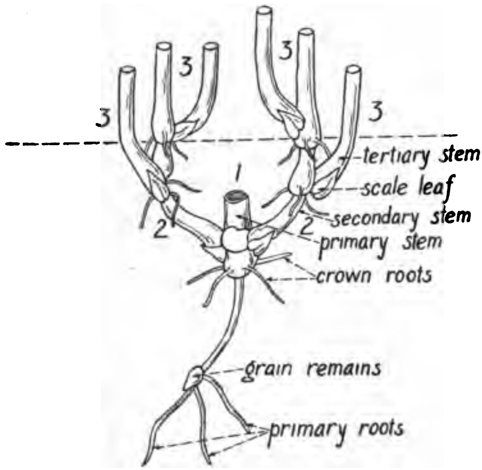


FIG. 47.—Diagrammatic representation of tillering in cereals. (*Robbins after Schindler.*)

erect itself again, but at an angle. This is in response to the stimulus of gravity (geotropism). There remains on the upper side of each grass stem node a zone of cells capable of growth partly belonging to the enlarged base of the sheath and partly to the swollen node. The cells of the lower side of this nascent area begin to grow and the stem bends upward in response to this growth. The production of a number of new upright branches from the lower nodes of the stem in grasses is known as "mooting," "stooling" or "tillering" (Fig. 47). The individual branches are called "tillers" and the entire mass of branches is known as the "stool." This method of tillering is found in cultivated oats and wheat plants. Stoloniferous grasses are those which produce horizontal stems at or above the surface of the soil. The horizontal stems are called runners, or stolons, as in buffalo grass (*Buchloë*).

Leaves.—The leaves of grasses arise at the nodes, a single leaf at each node. They are arranged in two ranks (distichous) with the third leaf over the first leaf, so that this arrangement is represented by the fraction ½, standing for the distichy. The grass leaf consists of three parts, the sheath, the ligule and the blade. The sheath is always open, or split, along one side and may be half as long as an internode, as long, one and a half times as long, twice as long as the internode along side of which it arises from the node below. The ligule, or rain-guard, takes on various forms. Usually it is membranous and fits tightly like a collar around the stem preventing the dust-laden rain from running down inside of the sheath (Fig. 48). The blade of grass leaves is linear or ribbon-like with parallel veins and usually an acute, or acuminate apex. Grass leaves capable of rolling and unrolling show in cross sections a group of enlarged epidermal cells, between the vascular bundles, the bulliform cells. These cells absorb water in wet weather and the leaves flatten out. In dry weather, the bulliform cells lose water and the leaf blades roll up.

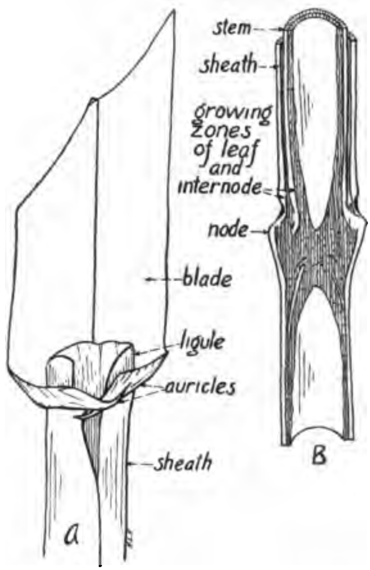


FIG. 48.—Barley. *A*, portion of leaf at juncture of leaf and blade; *B*, stem cut in median lengthwise section. ×2½. (*Robbins.*)

Inflorescence and Flowers.—The grass inflorescence, or flower cluster, is a spike of spikelets, a raceme of spikelets, or a panicle of spikelets. The spikelet is the ultimate division of the inflorescence and its parts are arranged in a distichous manner on a shortened axis known as the rachilla. The lower scales of the spikelet are bractlets known as the glumes. These are always empty and do not have flowers in their axils. Above these glumes are the flowers, or florets (Fig. 49). The variations in the morphology, arrangement, etc., of the spikelets are of the most diverse kind, and upon these characters depend largely the classification of the grasses.

Sometimes there is only one flower in the spikelet. This may be hermaphrodite, or it may be staminate, or pistillate. Frequently the spikelet has several to many florets all of which are perfect, or the upper florets may be imperfect, or sterile, and the lowermost perfect, or vice versa. Sometimes the flower is represented in the spikelet by one of its subtending scale leaves. The bractlet which subtends the floret is known as the lemma (flowering glume) and the inner scale opposed to the outer is the palet, or palea (Fig. 50). Frequently the lemma bears a bristle-like outgrowth, or awn, and this may be barbed. In many grasses, the

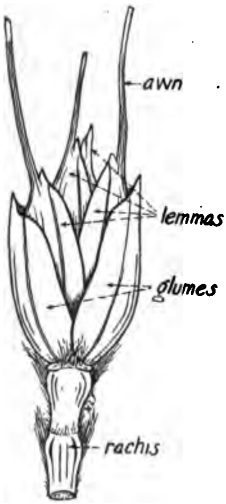


FIG. 49.

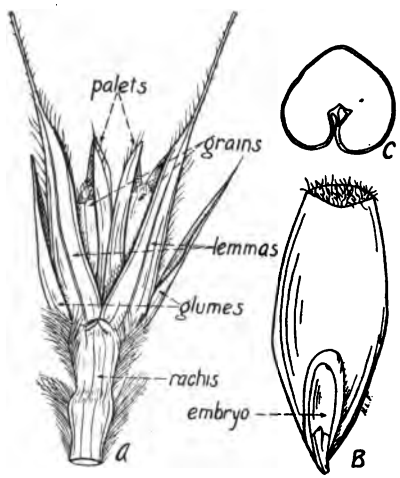


FIG. 50.

FIG. 49.—Single spikelet of common wheat (*Triticum æstivum*). ×2. (*Robbins.*)
FIG. 50.—Rye (*Secale cereale*). *A*, a single spikelet at a joint on the rachis; *B*, grain, external view; *C*, grain in cross-section. *A*, ×2½; *B* and *C*, ×5. (*Robbins.*)

perianth segments of ordinary monocotyledons, such as the lily, are represented by three (bamboos), two (most grasses), or a single small body known as a lodicule, or a squamula. It is the swelling of these lodicules which causes the separation of lemma from palet permitting the anthers and styles to emerge. A floret without lodicules never opens. The stamens of the grasses have long filaments and anthers, which are really adnate, but by the growth of the anther lobes below the point of attachment of the filament and the final swinging of the anther in the wind, the whole arrangement strongly suggests the versatile anther. Most grasses

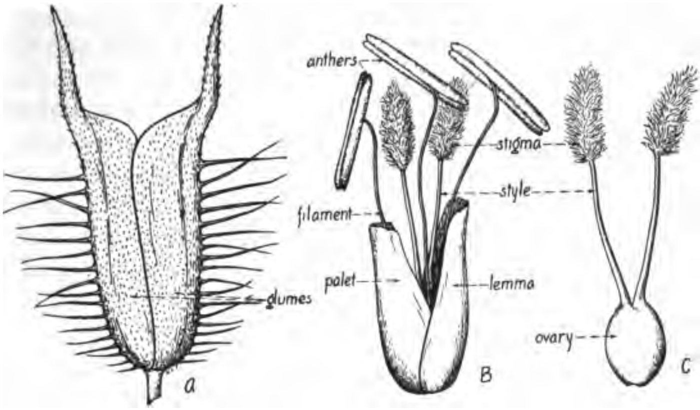


FIG. 51.—Timothy (*Phleum pratense*). *A*, single spikelet; *B*, spikelet with glumes removed; *C*, pistil. (*Robbins.*)

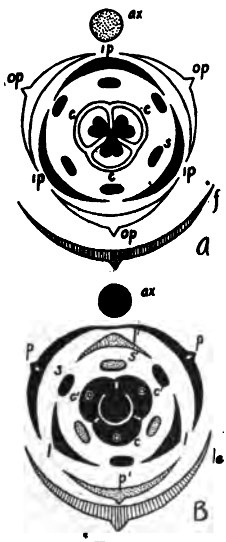


FIG. 52.

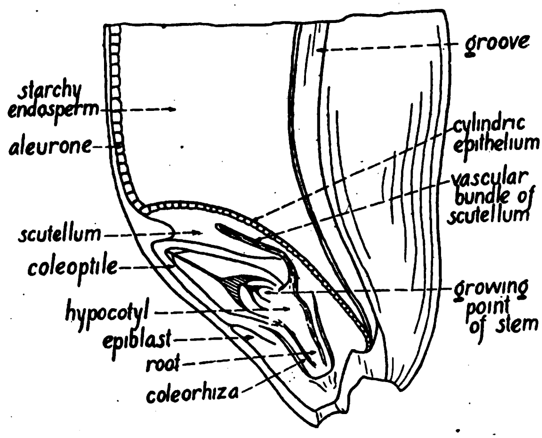


FIG. 53.

FIG. 52.—Diagram of *A*, lily flower, and *B*, grass flower showing homologous structures. *A*, *f*, bract; *ax*, axis; *op*, outer part of perigonium; *ip*, inner part of perigonium; *s*, stamens; *c*, tricarpellary 3-celled ovary. *B*, shaded structures are aborted; *le*, glume (bract); *ax*, axis; *p*, palet, and *p′*, lemma (outer perianth); *l* and *l′* lodicules (inner part of perigonium); *s* and *s′*, two whorls of stamens; *c*, tricarpellary 1-celled ovary. (*B. Robbins after Schuster.*)

FIG. 53.—Part of a median lengthwise section of a grain of wheat; much enlarged. (*Robbins after Strasburger.*)

have three stamens, some bamboos have six, while some grasses have two and even one stamen. The pollen grains are smooth and wind distributed (anemophily). The grass ovary is superior one-celled, one-ovuled and bears terminally two feathery styles, stigmatic along their whole hairy surface (Figs. 51 and 52). Maize has only one hairy style, but the presence of two vascular bundles suggests that it has arisen by the fusion of two elongated styles. Rice has occasionally three styles.

The fruit of grasses is one-seeded, dry and indehiscent, and hence, belongs to the class of achenial fruits. It is known as a caryopsis, or grain fruit. In this type of fruit the ovary wall (pericarp) is closely united to the seed coat, whereas in barley and oats the chaff firmly surrounds the ovary wall. The embryo is usually in touch with the seed coats on one side of the kernel and the reserve food, as starchy endosperm fills up the remainder of the space (Fig. 53). Sometimes, as in maize, there is in addition a horny endosperm which imparts hardness to the grain.

Economic Uses of Grasses

The forage grasses, those used as food for cattle, are of the most importance from an economic standpoint. "All flesh is grass" is as true today, as it was in bible times. They may be divided into three groups to be considered in detail in the next chapter, viz., the pasture grasses, the hay grasses and the fodder grasses. The cereals are those grasses which are grown for their grain. The most important are the common head wheat (*Triticum aestivum*), the durum wheat (*Triticum durum*), the oats (*Avena sativa*), the barley (*Hordeum vulgare*), the rye (*Secale cereale*), maize (*Zea mays*), the sorghums (*Andropogon halepensis*), which includes sorgo, kaffir, milo, broom corn, shallu, kowliang, dura, rice (*Oryza sativa*), wild rice (*Zizania aquatica*, *Z. palustris*) and millet (*Panicum miliaceum*).

The sugar-producing grasses are the sugar cane (*Saccharum officinarum*), maize (*Zea mays*) and Chinese sugar-millet (*Sorghum saccharatum*). The medicinal grasses include couch grass (*Agropyron repens*), the dried rhizome of which is collected in the spring, and a fluid extract made from it used as a domestic remedy in fever, jaundice, gout, etc. Its sole employment to-day is as a gentle, soothing diuretic in acute inflammations of the urinary passages. Other grasses have somewhat similar diuretic properties.

The edible grasses are mainly represented by the species of bamboo in

China, the tops of which are used as vegetables. Canned bamboo sprouts are not uncommonly found in the Chinese grocery stores in all of our large cities.

The best lawn grasses are the Kentucky blue-grass (*Poa pratensis*), red-top (*Agrostis alba* var. *vulgaris*) and the Rhode Island bent grass (*Agrostis canina*). For the extreme south, Bermuda-grass (*Cynodon dactylon*) and crab-grass (*Stenotaphrum americanum*) are the best.

The grasses which are suitable for the edgings, beds and borders of the garden are Provence cane (*Arundo donax, A. conspicua*), maize (*Zea mays*), pampas-grass (*Gynerium argenteum*), *Eulalia*, ribbon-grass (*Phalaris arundinacea* var. *picta*) and some of the Japanese bamboos which are hardy in northern latitudes. For interior decoration, the above grasses can be cut and used either singly, or in masses, but the inflorescences of the seaside oats (*Uniola paniculata*) are gathered for this purpose and also the tall red top (*Tridens flavus*), reed (*Phragmites communis*), reed meadow grass (*Glyceria septentrionalis*) and others which can be tied into bunches and placed in vases and other receptacles. The holy grass (*Hierochloë odorata*) is manufactured into fragrant baskets by the eastern Indians and the dried bleached straws of the Kentucky blue grass are woven into straw hats. The marram grass (*Ammophila arenaria*) is the most important species for the binding of the drifting sands of wandering dunes.

Paper can be made from the fibrous matter in the stems of a number of grasses principally maize from which a very good grade of paper can be made. Corn stalks have not been used extensively in this country as yet for paper, but with the fast disappearing spruce forests attention will no doubt be directed to maize as an abundant source of material for paper pulp. Esparto grass (*Macrochloa tenacissima*) is also extensively used in the manufacture of paper.

In the tropics, the bamboos of the larger size are used for a variety of purposes. They are used as the upright posts and rafters in house construction. In the split condition, they form the walls and partitions of the native houses and bungalows. They are used for roofing, for rain spouts, for water pipes, for flower pots, for buckets, for bridge construction and for many other purposes. The various species of bamboos are indispensable to the dwellers of the tropical countries of the world.

The vetiver, or kus-kus, is the very sweet-scented fibrous root of *Andropogon muricatus*, or grass of India, used to perfume rooms and to preserve clothing from the attack of insects. The roots are made into fans and worked into slips of bamboo to form the screens used to mitigate the heat in India.

Bibliography

CARRIER, LYMAN: The Identification of Grasses by their Vegetative Characters. Bull. 461, U. S. Department of Agriculture, January 19, 1917.

CLARK, GEO. H. and WALTER, M. OSCAR: Fodder and Pasture Plants. Department of Agriculture, Dominion of Canada, Ottawa, 1913.

LE MAOUT, EMM and DECAISNE, J., transl. by MRS. HOOKER: A System of Botany, Descriptive and Analytical. London, 1873, pages 880–892.

LINDLEY, JOHN: The Vegetable Kingdom. London, 1853, pages 106–116*b*.

RENDLE, ALFRED B.: The Classification of Plants. Vol. 1, Cambridge at the University Press, 1904, pages 220–241.

ROBBINS, WILFRED W.: The Botany of Crop Plants. A Text and Reference Book. P. Blakiston's Son & Co., Philadelphia, 1917, pages 69–90.

Laboratory Work

1. As this part of the botanical study will come in the early spring months fresh grasses, such as sweet vernal (*Anthoxanthum odoratum*), orchard grass (*Dactylis glomerata*), perennial rye grass (*Lolium perenne*) and Kentucky blue grass (*Poa pratensis*) may be studied. If this chapter is reached in the dead of winter, dried spikes of the common rye or any other large grass may be used to begin the study of the structure of the grass spikelet, glumes, lemma, palea, stamens, ovary and plumose styles. Whole rye plants, or other suitable grasses, should be gathered by the teacher just before the stamens protrude from the chaffy scales of the spikelet. Several hundred plants can be tied together with string and the bundle wrapped in newspaper to protect the plants from dust and hard usage. Such dried plants are almost as satisfactory for a detailed study of the rye as fresh specimens. Other grasses preserved in a similar way should be used for comparison with the rye. The drill should be on the structure of the spikelets and florets of each kind. Drawings should be made.

2. Kernels of corn, wheat and oats should be drawn and at the same time examined by the class. Attention should be drawn to all of the points in the external morphology of such grains.

3. Cut longitudinal and cross sections with a pen knife of both dry and soaked kernels of the above cereals and others, if time permits. Attention should be drawn to the varieties of corn as shown in section for starchy oil and protein. Treat the cut surfaces with iodine, which brings out nicely the relative position of embryo and reserve starch.

4. The class should be provided with stained sections of wheat for microscopic study to show pericarp, aleurone layer and starchy endosperm.

CHAPTER 12

DESCRIPTION OF IMPORTANT GRASS FORAGE PLANTS

There have appeared a number of important books on the subject of forage plants, and as these books are readily available to the student of agronomy, no attempt will be made in the following pages to give an exhaustive treatment of the forage grasses. The object will be to give a few of the essential details for the benefit of the student, who does not expect to study the forage plants exhaustively, but yet desires to have an acquaintance with the more important kinds.

Timothy, Herd's Grass (*Phleum pratense*).—This grass was introduced by Timothy Hansom of Maryland from England in 1720, hence the common name. It had an earlier introduction into cultivation by John Herd, who found it growing wild in New Hampshire, as early as 1700.

Description.—The plant is perennial with short rootstocks and, therefore, it has a somewhat tufted growth. The smooth stems are from two to five feet tall and in dry soil the base of the stem may be slightly bulbous. The leaves are rolled inward at first from one side and then are later expanded with short blades. The inflorescence is a close spike of spikelets (Fig. 54). The spikelets are one-flowered. Each flower is subtended by a hyaline, toothed, awnless lemma and a narrow hyaline palet. The subtending glumes of the spikelet are truncate with short awns and covered with stiff hairs. The caryopsis is ovoid from 1/15 to 1/12 inch in diameter, usually inclosed in the lemma and palet at maturity. There are about 600,000 to 2,000,000 seeds to the pound, the weight varying with the size of the seeds. The standard of germination is 90 per cent. and the purity of the seed should be not less than 98 per cent.

Soils.—Timothy is superior to any other grass for hay and it is well adapted for growth on cold, moist, or wet lands, particularly with heavy clay soils, although it succeeds best on moist loams and clays. It is not grown successfully on some soils, or in shallow soils with a rocky bed underneath. This grass shows innumerable unrecognized varieties only three or four of which are of agricultural importance. Although the

FIG. 54.—Timothy (*Phleum pratense*) grown in hard, dry soil. (*After Smith, Jared G.: Meadows and Pastures—Farmers' Bulletin* 66, 1904, *p.* 18.)

plant is perennial, there are biennial forms and tall annual forms. There is also a great range in the time of blooming.

Seeding.—The customary amount of timothy seed to sow, if used alone is 15 pounds, or one-third of a bushel per acre. If red clover is used with timothy, then the usual amount of timothy seed is 9 pounds, or one-fifth of a bushel per acre. It has been found by trial that better results are obtained by sowing the above amount than twice that quantity. The Rhode Island Agricultural Experiment Station recommends for meadows, the following per acre:

Timothy seed	15 pounds
Fancy red top	7.5 pounds
Red clover	7.5 pounds

Rotations.—The farmers of the North Atlantic and North Central states use timothy in nearly all of their rotations. The most common rotation consists of maize, oats and wheat each one year, followed by timothy and red clover for two or more years, the clover disappearing after one or more years. Timothy may be sown either in the fall or in the spring with any small grain that is sown at the time. A good stand will be obtained more frequently by sowing in the fall except in the dry prairie states of the northwest where the best results are obtained by spring sowing. As timothy is a late grass, the usual time of cutting is in July, and this is an advantage, because during the summer it cures more quickly, than if cut earlier.

Yield.—The total yield of dry matter per acre of timothy in Connecticut, when in full bloom, was 3,300 pounds, in Illinois 3,285 pounds, in Pennsylvania 2,585 pounds. When the seed was nearly ripe the yield per acre was in Connecticut 3,615 pounds, in Illinois 4,065 pounds, in Pennsylvania 3,065 pounds. Timothy generally produces between five and twelve bushels of seed per acre. The grass is most conveniently cut with the self-binder and is threshed with the ordinary threshing machine, using special sieves to clean the seed. Timothy hay contains about 6 per cent. protein, 45 per cent. of carbohydrates, 2.5 per cent. of fat and 29 per cent. of crude fiber, of these substances about half are digestible.

Kentucky Blue Grass, June Grass (*Poa pratensis*).—This useful grass is perennial with an extensively creeping rhizome, which produces leafy stems in bunches at intervals along its length. The stem of blue grass grows from 18 inches to 2½ feet tall. The basal leaves are longer than the upper stem leaves. The panicle is pyramidal with its slender remote branches with 3 to 5 fascicles. The spikelets are crowded, 3–5 flowered. The lemmas are cobwebby at the base (Fig. 55). This is a common grass in meadows and fields throughout the United States and in British Colum-

FIG. 55.—Kentucky blue grass (*Poa pratensis.*) (*After Ball, Carleton R.: Winter Forage Crops for the South, Farmers' Bulletin* 147, 1902, *p.* 19.)

bia. It is naturalized in the east, but is indigenous in the north and west. It gets its name Kentucky blue grass, because it thrives in the limestone soils of certain districts of Kentucky, which on this account are celebrated for their fine breeds of horses and cattle.

Adaptability.—This grass and its congener the Canadian blue grass (*Poa compressa*) (Fig. 56) are adapted to a cool, moist climate with 30 inches of rainfall and upward. They are resistant to cold, never freezing out in zero weather. They prefer well-drained loams, or clay loams some-

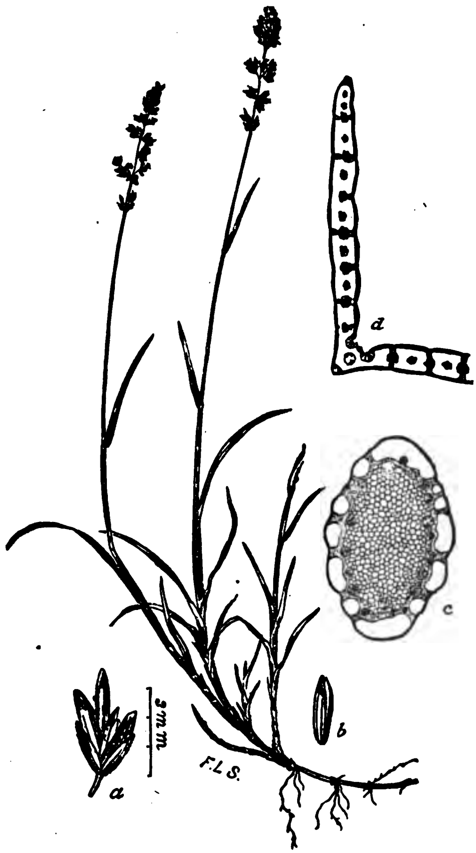


FIG. 56.—Canada blue grass (*Poa compressa*); *a*, spikelet; *b*, floret; *c*, magnified view of cross section of flattened stem; *d*, magnified cross section of a leaf blade. (*After Smith, Jared G.: Meadows and Pastures, Farmers' Bulletin*, 66, 1904, *p.* 24.)

what retentive of moisture, but are not well-suited for growth in sandy soils. The Canadian blue grass will grow on poorer soils than the Kentucky blue grass. The blue grasses are not suitable for hay, as the yield is low, but as pasture grasses and for the construction of lawns, they are unexcelled in the temperate regions of North America. They are valuable for summer pasture and winter pasture, and if used for the latter purpose they should not be closely pastured during the summer months. Drought inhibits the growth of Kentucky blue grass.

Seeding.—The number of seeds per pound varies from 2,185,000 to 3,888,000. Usually 40 pounds of commercial seed per acre is sown alone when a good stand is desired. It is usually mixed with other seeds in the formation of permanent pasture. The following is the usual composition of such mixtures, costing about $3 to $4 per acre.

Timothy	15 pounds
Kentucky blue grass	10 pounds
Meadow fescue	2 pounds
Red clover	8 pounds
White clover	2 pounds

The grass seeds of such a mixture are sown in September and the clover seeds, as early as possible in the spring. In the construction of lawns at least 40 pounds of 50 per cent. viable seed of Kentucky blue grass should be used alone or with white clover. In another formula for the making of lawns, the bulk of the seed used is Kentucky blue grass mixed with red-top and Rhode Island bent grass. The advantage of using several kinds of grass is that the first comers hold possession of the ground, or act as a nurse crop, until the stronger, but slower-growing, Kentucky blue grass gets complete root hold when, in the struggle for life, the earlier grasses are gradually excluded. Kentucky blue grass is considered one of the most troublesome weeds in New Zealand.

Redtop (*Agrostis alba*).—This native grass of North America is perhaps the third, or fourth most important perennial grass of our country. The culms are a foot (3 dm.) to 3 feet (10 dm.) tall from a creeping or stoloniferous rootstock. The leaves are flat, stiff and upright to lax and spreading. The panicle is contracted after flowering of a greenish, purple, or brown color with its branches slightly roughish. The spikelet is one-flowered. The lemmas nearly equal the glumes. They are 3-nerved, rarely short awned. The palea are one-half to two-thirds as long as the lemmas.

The variety *vulgaris* is known as Herd's Grass in Pennsylvania. It has shorter, more slender culms with smaller more branching panicles and narrow leaves. The variety *stolonifera* (not the *A. stolonifera*) is a form with stoloniferous habit used for lawns and is known as "creeping bent," *Agrostis canina*, is the Rhode Island Bent cultivated also as a lawn grass. Redtop resembles superficially Kentucky blue grass, but it is distinguished from the latter by the purple color of the panicle and the smaller and more numerous 1-flowered spikelets, while the spikelets of *Poa pratensis* are 3- to 5-flowered. Redtop flowers usually a month to two months later than the Kentucky blue grass. The seeds of redtop have a silvery appearance, one pound consisting of from 4,135,000 (Illinois Station) to 6,400,000 (North Carolina Station).

Sowing.—Redtop seed is usually sowed in amounts from 6 to 30 pounds per acre, when sown alone, and 6 to 10 pounds, when sown with timothy, or timothy and red clover. It should be sown about the same time as timothy. Like Kentucky blue grass, it is aggressive and frequently takes full possession of the land. Redtop thrives under a greater range of climate and soil than any other cultivated grass. Its value as a hay crop is next to timothy. It is adapted to low, moist lands and frequently forms one of the stages in the succession of grass herbage on old abandoned wagon tracts across grassland, or the open prairie. It will grow on poor soil, which it gradually improves.

Yield.—The yield of hay ranges from 3,000 to 5,000 pounds per acre. If harvested, when fully mature, it makes a fibrous and unpalatable hay. Analyses show that redtop hay contains more nutrients than timothy hay.

Orchard Grass (*Dactylis glomerata*).—Another name for this grass in England and New Zealand is cocksfoot. This grass with a bluish-green cast of foliage usually grows in clumps, as a bunch grass with culms 8 inches to 2 feet tall and broadly linear leaves. The spikelets are in dense one-sided clusters in close panicles. The spikelets are 2–5 flowered, compressed, nearly sessile in dense fascicles. The lemmas are 5-nerved with ciliate keels and are short awned. The palea are shorter than the lemmas. (Fig. 57).

Seeding.—The commercial seeds are enclosed in the chaff. Orchard grass can be purchased with 100 per cent. purity. The number of seeds per pound may vary from 400,000 to 480,000. When sown alone, 35 pounds of seed are used per acre, when intended for hay, and 15 pounds per acre, when intended for seed. It may be seeded either in the fall or very early in the spring, but whenever sown, it rarely gives a hay crop the first year.

Cultivation.—Orchard grass may come through the winter unscathed by the cold, but it is susceptible to late spring frosts after it has begun its growth. It grows well in the shade and grows best on a fairly fertile, well-drained soil. It requires a generous supply of moisture, but can stand periodic droughts fairly well and its duration is superior to timothy, when used for hay it should be cut as soon as it is in full bloom. Orchard grass is abundant about Philadelphia, but it can scarcely be said to be cultivated. Spillman in his "Farm Grasses of the United States" states that it is relatively most extensively cultivated in Virginia, North Carolina, Tennessee, namely, along the southern border of the timothy region. The Agricultural Experiment Station of Arkansas recommends the use of orchard grass for permanent meadows and pastures, as the best grass for that purpose. It also thrives west of the Cascade mountains in the Pacific northwest.

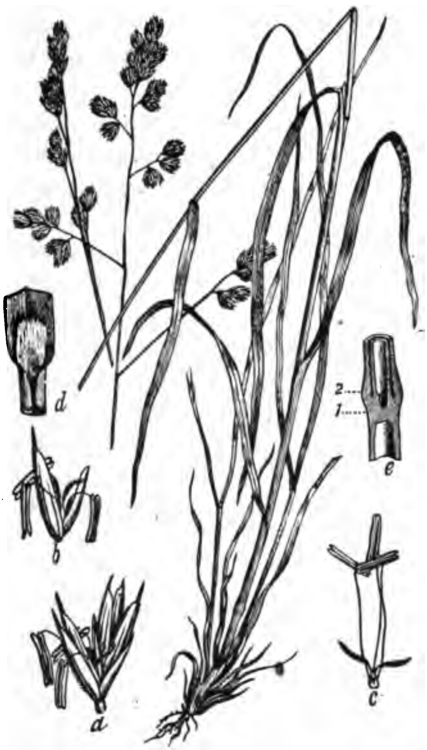


FIG. 57.—Orchard grass (*Dactylis glomerata*). (*After Ball, Carleton R.: Winter Forage Crops for the South, Farmers' Bulletin* 147, 1902, *p.* 21.)

Meadow Foxtail (*Alopecurus pratensis*).—This grass resembles timothy, for which it is sometimes taken by the uninitiated, but its stems are not so tall, its heads are shorter, and it blooms fully a month earlier than timothy. It grows 1–3 feet tall and develops short, creeping rhizomes. The sheaths of its leaves are loose, the upper usually inflated. The spikelets are 1-flowered, flattened. The lemma equals the acute, ciliate glumes with an exserted awn. The seed is produced sparingly, is of poor vitality, and therefore, costly. The number of seeds per pound is 1,216,006, and most of the commercial seed comes from abroad.

Growth and Hay.—It grows best on good soils and it is the chief grass of the richer natural pastures of Great Britain. It reaches maturity two, or three years after sowing and growing best in wet meadows, where it is to be ranked, as one of the earliest pasture grasses to start its growth in the spring. The hay of meadow foxtail is sweet and nutritive, especially before the formation of seed, as the sugar is drawn from stem and leaves and is used in the formation of the reserve materials of the seeds. It forms when grown an abundance of excellent pasture and all kinds of stock like it.

Smooth Brome Grass (*Bromus inermis*).—This is a grass of recent introduction, perennial by a creeping rootstock. The stems are stout forming heavy clumps, but when the soil is seeded abundantly these clumps unite to form a compact sod. The roots penetrate deeply, hence this grass is adapted to a wide range of climatic conditions. The panicles are large and with spreading branches. The spikelets are one inch long and brownish-red when old. Each spikelet has from seven to nine flowers, each enclosed by two more or less blunt scales. The lemmas are without awns.

Smooth Brome Grass thrives on loose comparatively poor land, where more valuable grasses might be a failure. It is valued because of its drought-resisting qualities producing in dry summers more green forage than any other grass. It is adapted to western Canada on account of its hardiness. It is sown at the rate of ten to twelve pounds of seed to the acre. It should be cut before flowering, as it becomes hard and less palatable. The smooth brome grass has been grown for centuries upon the steppes of Russia, hence it is adapted to a cold climate and a dry soil.

Blue-Joint Grass (*Calamagrostis canadensis*).—The blue-joint grass is a perennial with creeping rhizome which gives rise to culms 1–3 feet high with a clustered habit. The leaves are very rough, glaucous, flat and involute in drying. The panicle is spreading with the 1-flowered spikelets on slender branches and of a reddish-brown color. The glumes are equal, acute, scarcely longer than the lemma, which has an inconspicuous awn. The callus hairs are copious about as long as the floret. This grass is a native of wet places from eastern Quebec to New Jersey and westward and it flowers from June to July. It may be distinguished from red top by its awned lemma and the tuft of white silky hairs in each spikelet.

Blue-joint sometimes occupies large areas to the exclusion of other grasses. Hay made from it is of excellent quality and much relished by stock. Attempts to grow the grass experimentally at one of the agricultural experiment stations met with failure, because most of the seeds were found to lack vitality. Little is known about the feeding value of blue-joint grass. It is, however, of special value for places with very wet soil.

Fescue Grasses (*Festuca elatior* and *F. ovina*).—The taller, or meadow fescus is *Festuca elatior* (= *Festuca pratensis*) and the sheep's fescue is *F. ovina*. The first mentioned grass is the most important of the two species. It is a perennial grass with long fibrous roots with its erect culms reaching a height of 15 inches to two feet. The basal leaves have a shining surface and an intense, green color, while the stem leaves are flat, not involute, as in the sheep's fescue. The panicle is rather close with its branches bearing spikelets nearly to its base. The spikelets have lanceolate glumes, oblong-lanceolate lemmas, rarely short awned and scabrous at the apex. This grass is native to the meadows and waste places throughout the United States and southern Canada, naturalized from Europe and flowering from June to August.

Sheep's fescue, which has been introduced from Europe and has become naturalized in a few localities in the United States, is a fine-textured, small-growing species with a tufted habit, eaten by sheep quite freely, but avoided by cattle, if other grasses are more available.

Meadow fescue was early used as a constituent of the pasture mixtures sold by seedmen and in this way it has been widely distributed through the United States. Sown alone it furnishes scant pasturage during the hot summer months and the absence of rootstocks prevents its successful competition with Kentucky blue-grass. It is, however, appreciated in a few localities, such as the eastern parts of Kansas and Nebraska, where it has proved one of the best pasture grasses. It does well in wet places and survives the trampling by stock. It grows successfully on clay soils, although the soil best adpoted to the growth of the grass is on heavy black loam. The grass is seeded 10–15 pounds to the acre from August 15 to September 15, without the use of a nurse crop. It should be utilized more largely in the pasture mixtures of the east-central states.

Sweet Vernal Grass (*Anthoxanthum odoratum*).—This is a common, perennial grass of the meadows, pastures and waste lands in eastern United States. Agriculturally speaking it is a grass of secondary importance, growing from a foot to eighteen inches tall with close spike-like panicles and 3-flowered spikelets with the terminal flower perfect and the two lower florets represented solely by a lemma with a long basally attached awn. It flowers early in the season.

The dried grass has a characteristic, sweet odor due to the presence of cumarin which has been extracted from this and several other plants and used in the manufacture of perfume called "new mown hay." Cows feeding upon this grass have a grassy flavor imparted to the milk and the butter made from the milk. It was early introduced into America from Europe, where it is native, as also in western and north Asia and northern Africa.

FIG. 58.—Perennial rye grass (*Lolium perenne*). (*After Ball, Carleton R.: Winter Forage Crops for the South, Farmers' Bulletin* 147, 1902, *p.* 21.)

Perennial Rye Grass (*Lolium perenne*) and **Italian Rye Grass** (*L. italium*) (= *L. multiflorum*) are both of them short-lived, rapid-growing, perennial grasses with a tufted habit due to the intravaginal method of branching. Perennial rye grass may persist two or more years, while Italian rye grass rarely lasts more than two years. The axis of inflorescences of the perennial rye grass is smooth with the several flowered spikelets set solitarily in alternate notches of the axis of inflorescence with the edges of each spikelet placed against the rachis, so that the inner glume is lacking. The outer glume is rigid exceeding the lower florets (Fig. 58). The lemma of each floret is awnless, while in the Italian rye grass the lemma is provided with an awn. The foliage of the Italian rye grass is more abundant and the plant grows considerably taller.

Sowing and Adaptation.—Both species produce seed abundantly and germination of commercial seed is about 75 per cent. There are 336,000 seeds of perennial rye grass per pound and 285,000 of Italian rye grass. The farmer sows about 50 pounds of seed per acre, when sown alone, but the perennial rye grass is usually sown in mixture with other grass seeds. Italian rye grass is adapted to moist regions with mild winters. It succeeds best on loam and sandy loose soils being adapted for hay purposes and may be cut several times during the growing period. It can stand considerable drought, but it is not a suitable grass for districts where the summer is dry and hot, and hence, it will never assume any importance in the prairie regions.

Belonging to the same group is the tares of the Bible, or bearded darnel, *Lolium temulentum*, adventive from Europe but rare in grain fields and waste places.

FIG. 59.— Sand dune covered with marram grass (*Ammophila arenaria*), Gilgo Beach South Shore, Long Island, July 8, 1914.

Marram Grass (*Ammophila arenaria*).—A description of this grass is given here because of its unusual interest as a sand-binding plant. It is found on the sandy beaches and sand dunes along the Atlantic coast from New Brunswick to North Carolina and on the shores of the Great Lakes and in Europe (Fig. 59). It is a coarse, wiry perennial with a long creeping root-stock from which tufts of branches and green leaves arise at intervals in the growth of the rootstock through the mobile sand. As rapidly as the green parts are buried by the shifting sand the rhizome grows in length upward toward the surface giving rise to fresh aerial shoots. This spreading habit results in the plant presenting an obstacle to the movement of the dune sands, so that as the growth of the marram grass becomes more matted, the sands are effectually anchored (Fig. 60). In the latter part of August and early September, the pale, straw-yellow spike of spikelets grow up from the subterranean stem. It is propagated for sand-binding purposes by cutting the plant up into lengths, between the widely separated tufts, which are planted out in rows along with other protective devices. This method of fixing the wandering dunes has been used for many years on the Baltic coasts of Europe, in Holland, in Belgium, on Cape Cod and elsewhere with satisfactory results.

Fig. 60.—Sand dune with marram grass (*Ammophila arenaria*) and beach pea (*Lathyrus maritimus*), Gilgo Beach, South Shore, Long Island, July 8, 1914.

Seaside Oats (*Uniola paniculata*).—This stout grass is found on the sand hills and drifting sands of the American coast from Virginia to Florida and westward to Texas, where it produces a stout panicle bearing many oblong-oval, stramineous spikelets. These panicles are gathered by the people of such cities as Wilmington, N. C. and Charlestown, S. C. for decoration, being usually placed in vases for that purpose (Fig. 61). This grass to a certain extent takes the place of the marram grass in binding the sand of southern sea beaches and sand dunes. The description of this grass introduces us to a few additional species of grasses which are especially useful in the southern states. These grasses are:

Bermuda Grass (*Cynodon Dactylon*).—It is the most common and most valuable pasture grass of the southern states filling the same relative place in that region that Kentucky blue grass does in more northern states. It is a perennial grass spreading by runners, or by rootstocks, and is propagated also by seeds. The runners vary in length from a few inches to three or four feet, creeping over the ground and rooting at the joints (Fig. 62). The blades of the leaves are narrow, flat, one to four inches long, each with a ring of white hairs at the base. The slender flower spikes are formed three to six in a cluster radiating out from a common stalk in a digitate manner. Each spike is one to two inches long.

FIG. 61.—Seaside oat (*Uniola paniculata*) on dune at Wrightsville Beach, Wilmington, N. C., August 6, 1911.

Origin.—Bermuda grass is probably a native of India having been introduced to America somewhere about 1807, and it is now common in the southern states from Virginia to Florida westward to Arizona and California. In Australia, it is commonly known as couch, or Indian couch. It grows best in warm weather bearing the intense heat of summer without injury, but winter kills easily if subjected to heavy freezing. It thrives best on fertile soils not too wet, but better on heavy soils than on light ones. It will grow well on soils so alkaline that most other field crops and fruit crops will fail.

Seeding.—Bermuda grass produces seed abundantly in southern California, Arizona and New Mexico where most of the commercial seed is derived. It is propagated by seeds, or pieces of rootstocks. The yield of hay varies greatly with the locality in which it is grown, and on favorable soils, it may yield annually 6 to 8 tons of hay per acre. On soils of ordinary fertility, it will support about one steer per acre for eight to nine months, while on exceptionally favorable soils it may support four or five steers for a longer time. Its feeding value is fully equal to that of timothy, though its market value is usually less. Frequently, it becomes troublesome as a weed, when it can be eradicated by freezing the "roots," or by shading the ground by the growth of other crops.

FIG. 62.—Bermuda grass (*Cynodon Dactylon*). (*After Ball, Carleton R.: Winter Forage Crops for the South, Farmers' Bulletin* 147, 1902, *p.* 15.)

Johnson Grass (*Sorghum halepense*).—This is another grass which figures largely in the agriculture of the southern states. It is strongly stoloniferous with culms four to seven feet high with long flat leaves, and an open panicle six to eighteen inches long. It was introduced as Aleppo grass from Turkey in 1830 by Governor Means into South Carolina, and in 1844 into Alabama by Col. William Johnson for whom the plant is named. It is propagated by seeds, and if it is desired to control the plant, which sometimes becomes troublesome, it should never be permitted to go to seed. It is distributed as an avivectent, because the hard, outer covering of the seed is indigestible and passes through the digestive tract of cattle unchanged. It produces a large amount of good hay with an excellent quality. Usually two to

FIG. 63.—Broom-corn millet (*Panicum miliaceum*): *a*, *b*, and *c*, views of the spikelet and glumes, or chaff; *d* and *e*, two views of the "seed." (*After Williams, Thomas A.: Millets, Farmers' Bulletin* 101, 1899, p 20.)

three cuttings can be secured. It is not especially valuable as a pasture grass, because it does not stand grazing well.

Guinea Grass (*Panicum maximum*).—This is an important fodder grass in the West Indies, Mexico and other tropical countries where it is grown as a soiling crop. It is a perennial grass, but its roots are killed, if the ground is frozen. It has short rhizomes from which immense tufts of leafage are formed. It may be grown in Florida and the Gulf states, where the climatic conditions are favorable. It is not unusual in Mexico to see burros almost completely buried out of sight, except their ears and noses, with guinea grass, which is being carried to the nearest markets for sale. Sometimes ox carts are used to convey the guinea grass to the consumers. Hay is also obtained from the grass, although it is seldom used for the purpose. Another important species of *Panicum* is *P. miliaceum*, the broom-corn millet (Fig. 63).

Foxtail Millet (*Chaetochloa italica*).—This grass includes a number of different types such as the Hungarian (Fig. 64), Aino, German and Siberian millets.

FIG. 64.—A single plant of Hungarian millet (*Chaetochloa italica*). (*After Vinall, H. N.: Foxtail Millet, Farmers' Bulletin* 793, 1917, *p.* 12.)

The following two grasses are natives of the western plains states. They were used extensively by the wild herds of buffalos and eaten by the cattle upon a thousand ranches. They will figure largely in any attempt at restocking the cattle ranges with forage plants.

Grama Grass (*Bouteloua gracilis* = *B. oligostachya*).—This grass also called blue grama is found on the plains and prairies from Manitoba and Wisconsin to Mississippi, Arizona and Mexico. It is probably the most important of the grama grasses, which include six weeks' grama (*B.*

aristoides) side-oat grama (*B. curtipendula*) black grama (*B. eriopoda*) rough grama (*B. hirsuta*) hairy grama (*B. Parryi*) and other species of the genus. It forms very dense sod and withstands the trampling of cattle to a marked degree. It seems to grow more successfully when grazed and trampled to some extent, and under favorable conditions of soil it may grow sufficiently thick to be used as a hay grass. It is everywhere on the mesas and prairies forming a dense mass of herbage of fine and curly leaves arising from near the roots of the plant. The flowers bearing stems are 6 to 18 inches tall and bear near their summits two to three one-sided spikes in form like a tooth brush. This grass is easily propagated by seed which can readily be collected.

The side-oat grama is another common species and the most widely distributed of all the true gramas ranging from the Atlantic states westward to Arizona and south into Mexico. It is a conspicuous and important pasture grass in the rougher portions of the plain regions and in southern Arizona, it grows at altitudes mainly between 3,000 and 5,000 feet. The following analytical table gives the composition of this grass.

Material Analyzed	Percentage of Moisture	Water-free Basis (Per cent.)					
		Ash	Ether Extract	Crude Fiber	Nitrogen-free Extract	Protein	Pentasans
Santa Rita Mts., Ariz..	4.60	8.31	1.59	32.49	53.28	4.33	25.88
Average of 5 others.....	....	9.76	1.85	37.76	45.05	5.58	
Average of all..........	....	9.63	1.94	32.86	49.23	6.34	

Buffalo Grass (*Bulbilis* (*Buchloë*) *dactyloides*).—This pasture grass is found from the Dakotas to the Rocky mountains and south into Mexico. It is a creeping, stoloniferous, turf-forming, perennial grass giving rise to more or less curly leaves. The flower-bearing shoots are four inches to a foot tall and strictly dioecious. The staminate spikes usually overtop the leaves, while the pistillate spikes are shorter than the leaves. The staminate spikelets are 2–3 flowered. Pistillate spikelets are 1-flowered with indurated glumes, trifid at the apex. The lemma is narrow, hyaline inclosing the 2-nerved palea. The grain is free within the hardened glumes. The seedling plants are monœcious, but the staminate and pistillate branches produce vegetatively male and female plants as offshoots. It is a very hardy grass and it seems to be indifferent to drought. On the dry plains, it seldom grows over two to four inches tall, but in southern Texas, where conditions of heat and moisture are more favorable, it may become a foot high. It dry cures and furnishes in the dry state excellent winter grazing.

The following table gives the composition of buffalo grass.

Material Analyzed	Percentage of Moisture	Water-free Basis (Per cent)					
		Ash	Ether Extract	Crude Fiber	Nitrogen-free Extract	Protein	Pentasans
Bellevue, Texas.........	6.18	10.25	1.23	25.74	57.08	5.70	20.56
Average of 6 others.....	....	10.55	2.26	25.22	54.35	7.62	
		10.51	2.11	25.29	54.74	7.35	

Short Grass Vegetation.—A few words as to the growth of these two grasses from an agricultural-ecological standpoint. Representing the most typical form of the short-grass formation in eastern Colorado, the grama-buffalo-grass association presents an appearance of extreme monotony, according to H. L. Shantz. The plant cover is uniform and carpet-like in some places covering the whole surface of the ground in other places broken into alternating areas of open ground and dense mat-like cover. The amount of soil surface covered varies from as low as 10 per cent. to as high as 90 per cent., and the growth is the closest where there is a mixture of the two dominant grasses. When grama grass predominates there is an open-mat type of vegetation. A variety of other species, annual and perennial, are mixed with the grama and buffalo grasses and seasonally give some variety to the short-grass formation.

Short-grass vegetation is an indicator of rather short season favorable for growth. Grama grass requires approximately sixty days to mature and often fails to ripen its seed, largely because of insufficient water supply. Buffalo grass usually flowers and fruits early in the season, but when the early season is dry its fruiting may occur at any time during the summer when the water supply is sufficient. The principal adaptation of these grasses, according to H. L. Shantz, seems in their ability to dry out, as do many lichens and mosses, and to revive quickly when water is again supplied. During periods of excessive precipitation, both species of grasses grow and fruit luxuriantly. These short grasses have a very extensive surface-root system and are especially adapted to conditions found in the Great Plains region. After a slight rain, when only the first few inches of the soil becomes wet, these plants are able to absorb water and grow. Ordinarily grazing does not modify appreciably the short-grass cover. It seems to favor the development of the short-grass. Grass fires, if repeated, kill out the buffalo grass, but apparently grama grass suffers little. Extensive grazing causes the reversion of the short-grass stage to an earlier stage in the succession where *Gutierrezia sarothræ* and *Atemisia frigida* become dominant.

The presence of a short-grass cover indicates a growing season that is shortened by the limitation of the water supply. Crops which mature early are, therefore, more likely to succeed on this type of land than crops which require a longer season, such land is not adapted at all to deep-rooted crops unless the plants are grown far apart.

The above descriptions of a number of important agricultural grasses does not exhaust the list of native and introduced grasses, which in various parts of our wide domain figure largely in the composition of the vegetation of the inclosed meadows of the eastern states and the open wild ranges of the western states. A detailed account of all these grasses and their life histories would fill a large volume.

Bibliography

Ball, Carleton R.: Johnson Grass. Bulletin 11, Bureau of Plant Industry, U. S. Department of Agriculture, 1902.

Ball, Carleton R.: Saccharine Sorghums for Forage. Farmers' Bulletin 246, U. S. Department of Agriculture, 1906.

Bentley, H. L.: Experiments in Range Improvement in Central Texas. Bulletin 13, Bureau of Plant Industry, U. S. Department of Agriculture, 1902.

Brown, Edgar and Hillman, F. H.: The Seeds of the Blue Grasses. Bulletin 84, Bureau of Plant Industry, 1905.

Carrier, Lyman: Cost of Filling Silos. Farmers' Bulletin 292, U. S. Department of Agriculture, 1907; The Grazing Industry of the Bluegrass Region. Bulletin 397, U. S. Department of Agriculture, 1916.

Cates, J. S. and Spillman, W. J.: A Method of Eradicating Johnson Grass. Farmers' Bulletin 279, U. S. Department of Agriculture, 1907.

Clements, Frederic E.: Plant Indicators. The Relation of Plant Communities to

Process and Practice. Publication No. 290, Carnegie Institution of Washington, 388 pages, 92 plates, 1920.

Corbett, L. C.: The Lawn. Farmers' Bulletin 248, U. S. Department of Agriculture 1906.

Cotton, J. S.: Range Management in the State of Washington. Bulletin 75, 1905; The Improvement of Mountain Meadows. Bulletin 127, Bureau of Plant Industry, U. S. Department of Agriculture, 1908.

Davy, Joseph Burtt: Stock Ranges of Northwestern California. Notes on the Grasses and Forage Plants and Range Conditions. Bulletin 12, Bureau of Plant Industry, U. S. Department of Agriculture, 1902.

Dillman, Arthur C.: Breeding Drought-resistant Forage Plants for the Great Plains Area. Bulletin 196, Bureau of Plant Industry, U. S. Department of Agriculture, 1910.

Denton, A. A.: Sorghum Sirup Manufacture. Farmers' Bulletin 35, 1901.

Evans, Morgan W.: Timothy. Farmers' Bulletin 990, U. S. Department of Agriculture, 1918.

Gardner, Frank D. and Collaborators: Successful Farming. The John C. Winston Company, Philadelphia, 1916.

Griffiths, David: Range Improvement in Arizona. Bulletin 4, 1901; Forage Conditions on the Northern Border of the Great Basin. Bulletin 15, 1902; Forage Conditions and Problems in Eastern Washington, Eastern Oregon, Northwestern California, and Northwestern Nevada. Bulletin 38, 1903; Range Investigations in Arizona. Bulletin 67, 1904; The Reseeding of Depleted Ranges and Native Pastures. Bulletin 117, 1907; A Protected Stock Range in Arizona. Bulletin 177, 1910, Bureau of Plant Industry, U. S. Department of Agriculture.

Griffiths, David, Bidwell, George L. and Goodrich, Charles E.: Native Pasture Grasses of the United States. Bulletin 201, U. S. Department of Agriculture, 1915.

Hansen, Albert A.: Eradication of Bermuda Grass. Farmers' Bulletin 945, U. S. Department of Agriculture, 1918.

Hillman, F. H.: Distinguishing Characters of the Seeds of Sudan Grass and Johnson Grass. Bulletin 406, U. S. Department of Agriculture, 1916.

Hitchcock, A. S.: Cultivated Forage Crops of the Northwestern States. Bulletin 31, 1902, Bureau of Plant Industry.

Hunt, Thomas F.: The Forage and Fiber Crops in America. Orange Judd Company, New York, 1912.

Hunter, Byron: Pasture and Grain Crops for Hogs in the Pacific Northwest. Bulletin 68, U. S. Department of Agriculture, 1914; Farm Practice with Forage Crops in Western Oregon and Western Washington. Bulletin 94, Bureau of Plant Industry, U. S. Department of Agriculture, 1906.

Jardine, James T.: Range Management on the National Forests. Bulletin 790, U. S. Department of Agriculture, 1919.

Jones, L. R.: Vermont Grasses and Clovers. Bulletin 94, Vermont Agricultural Experiment Station, May, 1902.

Lyon, T. H. and Hitchcock, A. S.: Pasture, Meadow and Forage Crops in Nebraska. Bulletin 59, Bureau of Plant Industry, U. S. Department of Agriculture, 1904.

LAMSON-SCRIBNER, F.: Our Native Pasture Plants. Yearbook of the Department of Agriculture, 1900, 581–598; Southern Forage Plants. Farmers' Bulletin 102, U. S. Department of Agriculture, 1899.

MCCLURE, HARRY B.: Market Hay. Farmers' Bulletin 508, U. S. Department of Agriculture, 1912; Haymaking. Farmers' Bulletin 943, 1918; Hay Stackers. Farmers' Bulletin 1009, 1919; Baling Hay, Farmers' Bulletin 1049, 1919.

OAKLEY, R. A.: Canada Blue Grass, Its Culture and Uses. Farmers' Bulletin, 402, U. S. Department of Agriculture, 1910.

PIETERS, A. J. and BROWN, EDGAR: Kentucky Bluegrass Seed Bulletin 19, Bureau of Plant Industry, U. S. Department of Agriculture, 1902.

PIPER, C. V.: Grass Lands of the South Alaska Coast. Bulletin 82, Bureau of Plant Industry, U. S. Department of Agriculture, 1905.

PIPER, C. V. and HILLMAN, J. H.: The Agricultural Species of Bent Grasses. Bulletin 692, U. S. Department of Agriculture, 1918.

PIPER, C. V. and OAKLEY, R. A.: Turf for Golf Courses. New York, The Macmillan Company, 1917, pages 262.

SAMPSON, ARTHUR W.: Range Improvement by Deferred and Rotation Grazing. Bulletin 34, U. S. Department of Agriculture, 1913; Important Range Plants, their Life History and Forage Value. Bulletin 545, U. S. Department of Agriculture, 1917; Plant Succession in Relation to Range Management. Bulletin 791, U. S. Department of Agriculture, 1919.

SHANTZ, H. L.: Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area. Bulletin 201, Bureau of Plant Industry, U. S. Department of Agriculture, 1911.

TRACY, S. M.: Some Important Grasses and Forage Plants for the Gulf Coast Region. Farmers' Bulletin 300, U. S. Department of Agriculture, 1907; Forage Crops for the Cotton Region. Farmers' Bulletin 509, 1912; Bermuda Grass. Farmers' Bulletin 814, 1917.

VINALL, H. N.: Meadow Fescue, its Culture and Uses. Farmers' Bulletin 361. U. S. Department of Agriculture, 1909; Foxtail Millet, its Culture and Utilization in the United States. Farmers' Bulletin 793, 1917.

WILLIAMS, THOMAS A.: Timothy in the Prairie Region. Yearbook of the U. S. Department of Agriculture, 1896, 147–154; Sorghum as a Forage Crop. Farmers' Bulletin 50, U. S. Department of Agriculture, 1897.

WITTE, HERNFRID: Breeding Timothy at Svalöf. Journal of Heredity, x: 291–299, October, 1919.

WOODWARD, T. E. and OTHERS: The Making and Feeding of Silage. Farmers' Bulletin 556, U. S. Department of Agriculture, 1913.

WOOTON, E. O.: Factors Affecting Range Management in New Mexico. Bulletin 211, U. S. Department of Agriculture, 1915.

YERKES, ARNOLD P. and MCCLURE, H. B.: Harvesting Hay with the Sweep-rake. Farmers' Bulletin 838, U. S. Department of Agriculture, 1917.

YODER, P. A.: Growing Sugar Cane for Sirup. Farmers' Bulletin 1034, U. S. Department of Agriculture, 1919.

Laboratory Work

Suggestions to Teachers.—As previously emphasized, the teacher should provide the material for laboratory work and demonstration some time in advance. The material for study should consist of fresh dried and alcoholic specimens. If the ground around the laboratory permits, a grass garden should be started, where at least all of the more important grasses used in the class work should be grown in plots. Although most of this fresh material can be used only during the growing season, some of it, especially the underground parts, can be secured if the ground is not frozen too hard during the winter months. The alcoholic and dried specimens should represent either whole or parts of the plants. Fruits of all the species studied should also be on hand for examination. Photographs and illustrations of other kinds, wall charts and maps of distribution will prove useful. Moving pictures of agricultural operations, such as seed sowing, mowing, haying operations, etc., will prove of great value, if the laboratory is equipped with all of these modern pieces of apparatus. As many of the above mentioned grasses are cultivated in all civilized countries or have escaped from cultivation the teacher, wherever he or she may be located, need not suffer for lack of material.

Laboratory Exercises

1. Describe and draw the specimens of grasses handed to you for study. The examination of the grass flower can only be accomplished successfully by the use of a hand lens, or a dissecting microscope. The equipment of the laboratory presupposes that each student has access to such a microscope. The dried grasses for study can be mounted by the teacher on stiff card boards covered with thin sheets of gelatin, or what is better the specimens themselves can be presented to the students for preservation.

2. Each student will have assigned a single grass species to study in the field, as it grows, and with reference to the literature dealing with this plant species. This will necessitate reference to the books, cyclopedias, bulletins and other sources of information available in the library of the institution, or if the laboratory is in a large city, the libraries of the scientific institutions which may be located there. A written report should be handed to the teacher as a result of each investigation. This is a piece of home work which should be a part of every course in botany, as it indicates to the students the sources of the information about the plants with which the class deals. It also indicates how knowledge is acquired about books and the objects of nature. It trains the student for future investigation and conduces to originality.

3. A comparative study of the grain fruits, or caryopses of the different grasses should be a part of the laboratory training. The writer has used a set of six pasteboard cards perforated with round holes an inch in diameter. These cards are backed with a stiff piece of gray pasteboard. The students are given the different agricultural seed grass caryopses, leguminous, weed and poisonous seeds to the number of forty-eight. These are filled into the circular holes made as above described. The eight holes each with a different seed are then covered by a single piece of glass usually the size of lantern slide covers. The glass is then bound to the two separate pieces of cardboard by passe-partout tape usually black in color. The six sets of eight seeds each

are then kept in a pasteboard box with a front which can drop down and a lid hinged to the back of the box. Such sets have been mounted for a number of years by students at the University of Pennsylvania, but the writer has given up this method in favor of the distribution of 48 aluminium-capped vials in which the agricultural seeds will be kept. Tape labels, such as are used for attachment to envelopes with the return address will be printed with the scientific and common name of each poisonous, grass, leguminous and weed seed. These can be readily pasted on the vials, when the seeds are distributed to the class. The vials will be kept in four paper trays with twelve compartments each made to accurately accommodate the vials. The box in which the trays fit will have a front side, which will drop down, and a hinged lid provided on the outside with a neatly printed label describing the contents of the box. Such a box with vials should not cost each student over three dollars, if bought in quantity at present prices prevailing (1920).[1] With these sets of seeds, it will be possible for the class to make a comparative study of the most important agricultural seeds. With the set of 48 seeds, now used at the University of Pennsylvania, the students, as a part of the practical work required of them in their final examination in botany, are required to identify on request any five or ten seeds of the set of forty-eight. During the instructional period, drawings of each of the forty-eight seeds should be made with the aid of hand lenses.

4. The most important grass fruits should be studied in sections after the external study has been completed by the application of iodine solution. This will enable the student to differentiate the embryo and the reserve food in a more perfect way. Microscopic sections can be made, but time will hardly be found for a detailed study of them.

[1] The author has adopted the expedient of dividing the cost between the school and the students. The school pays one-half and the students (with their consent) the other half deducted to save embarassment from the students' deposited laboratory fees. The boxes were made for the author by the Jesse Jones Paper Box Co., 615 Commerce Street, Philadelphia. The vials (No. 21) with screw tops (aluminium) were furnished by Whitall Tatum Co., Glass Manufacturers, 410 Race Street, Philadelphia and the gummed labels by the Dennison Manufacturing Co., 1007 Chestnut Street, Philadelphia. The box labels were printed by a local printer.

CHAPTER 13

THE MOST IMPORTANT CEREALS

The grasses, which are grown for their grains, are known as cereals. These grasses gathered at first by uncivilized men for their grain fruits slowly came into cultivation, as men left the hunting and pastoral stages and became agriculturists. The ancient inhabitants of China, Babylonia, Egypt, North and South America at an early date cultivated the cereals. The most important cereals in the United States in the order of their production are Maize (Indian corn), Oats, Wheat, Barley, Rye, Rice, Buckwheat. The average production of them in the United States for the period 1911–13 was in bushels as follows:

Maize (Corn)	2,701,074,000 bushels.
Oats	1,154,134,300 bushels.
Wheat	704,995,000 bushels.
Barley	187,417,700 bushels.
Rye	56,721,000 bushels.
Rice	11,808,700 bushels.

The above cereals will be treated of in the order of their production in the United States.

Maize, Indian Corn, Corn (*Zea mays*).

Origin.—Maize is undoubtedly a native of America and the evidence points to Mexico as the original home of the wild species. It was cultivated from ancient times among the agricultural tribes of North and South America. The wild form is not known definitely, but teosinte. *Euchlaena mexicana*, is the nearest known wild relative of maize and the two plants readily hybridize. Montgomery, Collins, Weatherwax, and the writer have proposed various theories, as to the origin of maize in its cultivated forms, but the theoretical discussion of this interesting matter will not be solved finally until either a wild progenitor of maize is discovered by some fortunate botanist, or the cultivated maize (cultigen) is produced synthetically from maize and teosinte combined, as some botanists think that the cultivated plant is of hybrid origin, or from teosinte alone.

Description.—Maize is a summer annual and is dependent upon man for its reproduction, not sowing itself from seed, as a wild plant (Fig. 65). Its root system is fibrous, but in addition there are aerially developed prop roots which soon become fixed in the soil. The stem of corn is solid with the closed, collateral sap-bundles scattered in a cross-sectional view. Frequently corn produces suckers which correspond with the stools of wheat. Suckers of corn are undesirable, as they are heavy soil feeders and reduce the yield through nonproduction of ears. The leaves are two ranked with large, broad blades at the base of which is a conspicuous membran-

Fig. 65.—Field of maize at Sea Girt, N. J., August 23, 1919.

ous ligule, or rain-guard. Corn is monœcious. The pistillate flowers are borne in a spike, or ear, surrounded by the bases of transformed leaves, or husks. The male flowers are produced in a terminal tassel. The pistillate spikelets are arranged in rows along a fleshy axis, or cob. Each normal pistillate spikelet has two flowers, the lower (outer) one of which is abortive, but this floret is represented by the persistent lemma and palea (Fig. 66). The spikelet is subtended by two glumes that are shorter than the ovary, very broad and fleshy at the base, thin membranous above and fringed on the edges. The lemma and palea of the fertile flower are short, broad and membranous. The single ovary bears a long style, or thread of silk. The tassel, or panicle of staminate spikelets is terminal in maize. Each normal staminate spikelet is two-flowered, each flower

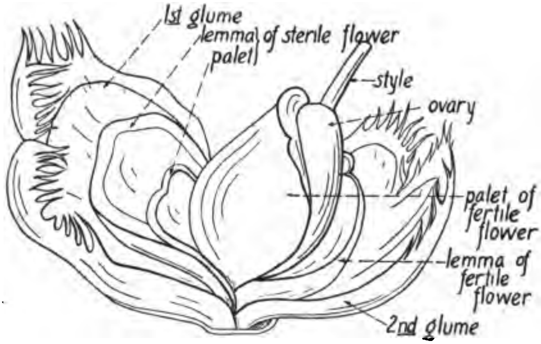


FIG. 66.—Pistillate spikelet of corn, much enlarged. (*Robbins after Nees.*)

having three perfect stamens subtended by lemmas and palets. Glumes subtend each staminate spikelet (Fig. 67).

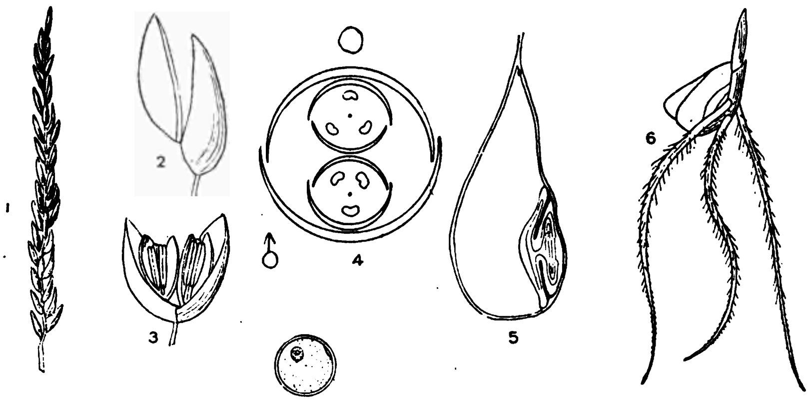


FIG. 67.—Details of maize (*Zea mays canina*) 1. Male inflorescence; 2. Two male spikelets; 3. Dissection of spikelet with two male flowers (below a pollen grain); 4. Plan of male spikelet; 5. Vertical section of maize kernel; 6. Germination of maize caryopsis. (*After Harshberger, John W.: Maize: A Botanical and Economic Study. Contributions from the Botanical Laboratory, University of Pennsylvania* I, *No.* 2, *Part of Plate II*. 1893.)

Grain.—The mature grain of corn is flattened with an external shallow groove which indicates the position of the embryo, and at the blunt end a small scar where the style was attached. Cutting the kernel open, we find the embryo at one side with the rest of the interior filled with starchy, or horny reserve food. Increase the starchy reserve food and you increase the carbohydrate content of the grain. Increase the horny

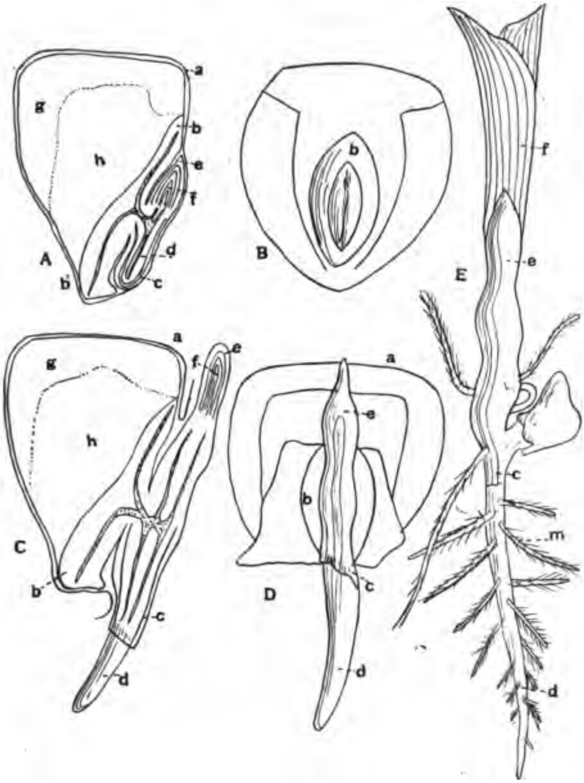


FIG. 68.—Structure and germination of maize kernel, *A*, longitudinal section of maize grain showing position of embryo and reserve food; *B*, top or flat side of kernel; *C*, longitudinal section in early stages of germination; *D*, early stage of germination, same view as in *B*; *E*, later stage of germination when maize has become independent. *a*, outer coat of fruit; *b*, scutellum; *c*, root sheath or coleorrhiza; *d*, radicle; *e*, cotyledon; *f*, plumule; *g*, horny reserve food; *h*, starchy reserve food; *m*, secondary roots.

reserve food and the protein contents are increased. A large embryo, or germ, indicates a kernel rich in oil (Fig. 67). In the germination of the corn grain, the optimum temperature is 91°F. a maximum of 114.8°F. and a mininum of 41°F. The primary root first projects then bursts through the coleorhiza and later the secondary roots appear about the time that the plumule grows upward (Fig. 68). Collins describes some pueblo corn

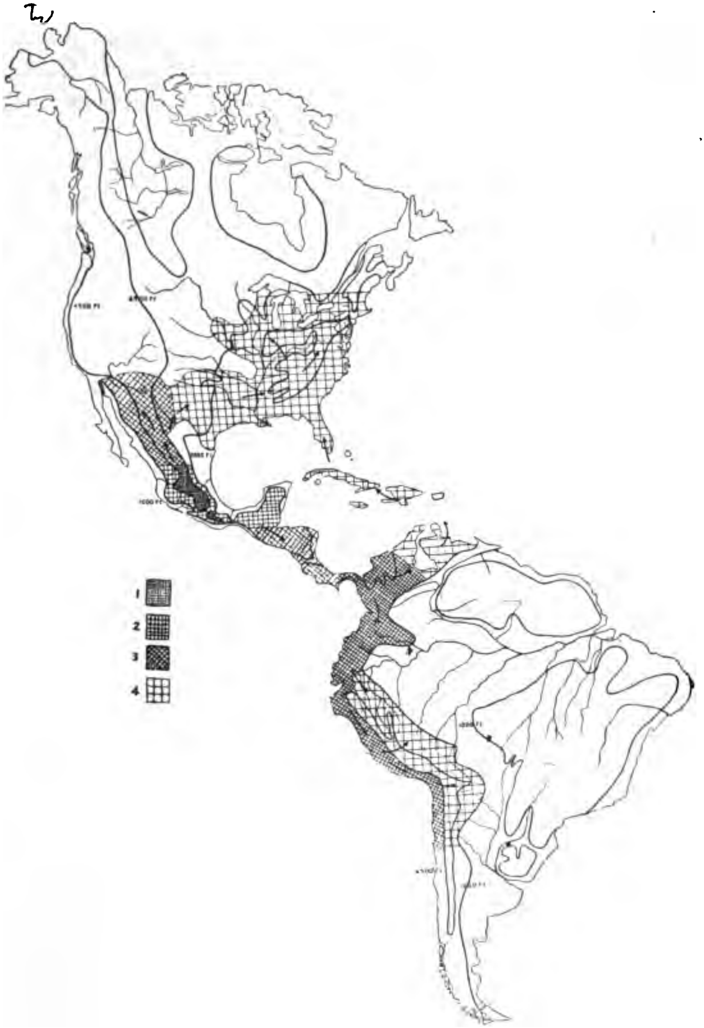


FIG. 69.—Map showing the original home of maize with its geographical distribution and aboriginal culture in space and time. Squares indicate: 1, Original home of maize; 2. Limits of primitive cultivation; 3. Limits reached prior to the year 700 A.D.; 4. Limits reached by the year 1000 A.D. (*After Harshberger, John W.: Maize: A Botanical and Economic Study. Contributions from the Botanical Laboratory, University of Pennsylvania I, No. 2, Plate IV,* 1893.)

which is planted very deep in the soil at least a foot, or eighteen inches. Corn with such a habit can reach the water in the deeper soil levels and is adapted to an arid climate.

Soils.—The best corn soils are well drained, deep, warm, black loams, with a high per cent. of organic matter and available nitrogen. Varieties are known which mature in 80 days, where the summer temperature is over 65°. Even these requirements nowhere permit it to mature beyond 50°N. though it is grown for fodder in southern England and in Quebec. At least 20 inches of rainfall seem necessary for the best growth of the corn plant.

Maize is the principal food supply of the American people. The original distribution of the plant is shown in the map (Fig. 69). Outside of the south very little corn is consumed as a human food for most of the corn is fed to cattle or hogs and consumed as meat. The maize grown in the South is practically all of it consumed at home, being turned into hog flesh, hoecake and hominy. While corn meal hominy and similar products are the principal corn foods, there are a number of others such as the unripe ears, especially of sweet varieties and pop corn which are used as favorite American foods. Starch, glucose, gluten, oil and corn flakes are also made from corn.

Cultivation.—Maize is of the utmost importance from an agricultural viewpoint and it has been studied as no other cereal in America with regard to methods of cultivation, improvement of varieties, composition, position in the rotation and as a food for man and the domestic animals. The important food materials found in corn and its products are: (1) Protein, or nitrogenous, flesh-forming material; (2) Fat; (3) Carbohydrates, or heat-producing elements, such as, starches, sugars, cellulose, or crude fiber; (4) Mineral matter and ash. The food value of the grain of maize lies in its high net available energy due to the presence of carbohydrates and fats. The plant whether green, ensiled, or dry is a good food for horses and ruminants, the dry matter being more digestible than that of clover hay, or timothy hay. When properly prepared the food value of the dry matter is rather less, and when the grain is added, rather more than that of timothy hay. The digestible nutrients in the grain and clover are about as two to one. The nutrient ratio of maize is 1:7.5 and its nutritive value is 87. This ratio indicates that maize is poor in protein substances at the best. This rather unfits it for a standard article of food, unless combined with other substances richer in protein.

Sowing.—The North American Indians believed that the time to plant corn had arrived when the young leaves of the white oak in the spring had reached the size of squirrel ears. This period is reached in Pennsylvania about the first week of May, and in the Gulf states about the middle of February to the beginning of March. The Indian method of planting maize was to put four grains in a hill four feet each way and they taught this method to the white settlers. The usual method in the North Atlantic states is to plant in drills; in the North Central states the practice is divided, but the larger part is planted in hills, while in the South, it is usually planted in hills in the lowlands while in hill country maize is drilled, so that all cultivation may be at right angles to the slope of the hill which method prevents washing. The cultivation of maize during its early development prevents the growth of weeds and stirs the soil. The destruction of weeds is a most important matter as they compete seriously

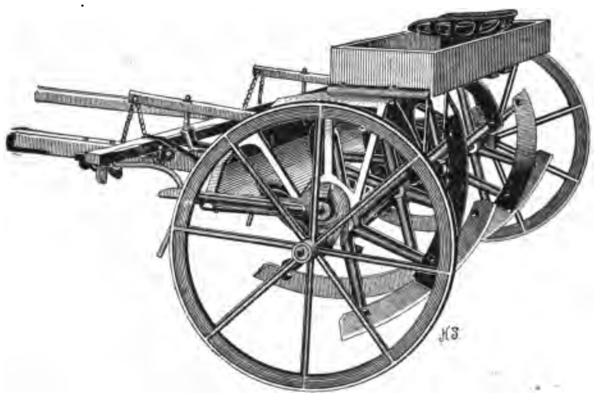


FIG. 70.—Three-horse corn-stalk cutter which cuts two rows. (*After Hartley, C. P.: Harvesting and Storing Corn. Farmers' Bulletin* 313, 1907, *p.* 27.)

with the corn plants. Deep cultivation should be practiced early in the season in order to conserve the soil moisture. Shallow cultivation should be pursued late in the season, as it saves the feeding corn roots. The frequency of cultivation will depend chiefly on the surface condition of the soil and the presence of weeds. Improved machinery is used for the cutting of the corn crop (Fig. 70).

Rotation.—Most farmers in Indiana maintain a general rotation of corn one year, wheat or oats one year, and hay or pasture one or two years. Some timothy is grown, but most of the hay is clover. In Mercer County, New Jersey, south of Trenton, the rotation is corn one year, potatoes one year, rye or wheat one year and hay one or two years. About 35 per cent. of the farmers grow crimson clover and rye, or vetch, as cover crops after corn. In portions of Ohio there is a three-year rotation of corn, wheat and clover. The following five year rotation has been found successful: Clover, timothy, corn, oats, wheat. In the south, there are 3 Cs, viz., corn, cowpeas, cotton.

The larger part of the crop of corn is still husked by hand from the standing plant, which is then cut and put into shocks, or into the silo. In the silo by process of fermentation, it is converted into silage: After being husked, the ears of maize are placed in cribs which are open-slatted storehouses permitting the circulation of the air. Some of the finer ears are laid aside as seed corn.

Oats (*Avena sativa, A. orientalis* and *A. nuda*).—There are three species of oats in common cultivation in the United States (Fig. 71, *A* and *B*). They are the panicle oats (*Avena sativa*), banner oats (*A. orientalis*) and naked oats (*A. nuda*). Several botanists believe that these three cultigens have originated from the wild oats (*Avena fatua*). There are other cultivated oats but they are of minor importance.

Description.—The roots of oats extend to a depth of four or five feet. The stems of the plant are larger in diameter and softer than wheat and bear leaves abundantly. The leaves have a closed leaf sheath and the ligule is short and toothed. The spikelets of the oats are arranged in open panicles with a one-sided panicle in banner oats. The spreading oats, *Avena sativa*, has a panicle with its branches spreading in all directions. An oat spikelet has two to five flowers with two unequal glumes at the base of the spikelet. The lemma is rounded on the back and with a dorsal awn. The palea is two-toothed and shorter than the lemma fitting closely about the grain. Each floret has three stamens. The blooming of the flowers in an entire spikelet is completed in about a week with the lower floret developing first and the others in ascending order. The flowering period is from 2 to 4 p.m. Self-pollination is the rule, although cross pollination is not impossible. The elongated hairy oat kernel is firmly surrounded by the lemma and the palet which together form the hull. The starchy endosperm of oats, unlike that of wheat, has no gluten and hence it cannot be made into a light head.

Cool summers favor the ripening of the grain of oats, and hence, the plant is better adapted to high altitudes and latitudes. The plant requires more water than the other common cereals, and hence, the crop is generally grown in the spring. The plant is more independent of the character of the soil than any other cereal.

FIG. 71.—Heads of oats grown at the Moro substation: *A*. Sweedish select, a banner oats, *Avena orientalis* and *B*, Kherson, a panicle oats, *Avena sativa*. (*After Stephens, David E.: Experiments with Spring Cereals at the Eastern Oregon Dry Farming Substation Moro, Oregon. Bull.* 498, *U. S. Department of Agriculture*, 1917, *p.* 28.)

Large quantities of oats are used every year in the form of oatmeal and rolled oats. The grain is extensively used as a feed for horses, and occasionally, it is fed to poultry. The oat plant may be grown for pasture, for hay, or as a nurse crop. Oat straw is a valuable food for cattle and sheep. The United States leads all other countries in the production of oats with Russia a close second.

Quality.—The quality of oats depends principally upon the proportion of hull to kernels. American varieties, as a rule, have on an average about thirty per cent. of hull and seventy per cent. of kernel, and as these percentages vary the composition of the grain varies also. Oats differ from maize in having a larger per cent. of crude fiber at the expense of the starch. The kernel is richer in fat and protein than any of the other cereals. Oat straw has a higher percentage of protein and a lower percentage of crude fiber than rye, or wheat straw.

Rotations.—Oats generally follow maize in rotations. The following is recommended by Hunt. For winter wheat sections, maize, one year; oats, one year; winter wheat, one year; timothy and common red clover, one or two years. For sections specially adapted to maize and not to wheat, maize, two years; oats, one year; timothy and clover, one to three years, depending upon the live stock kept. For southern states: maize and cowpeas, one year; oats followed by cowpeas harvested for hay, one year; cotton, one or two years. In the first year of this rotation, the cowpeas grown between the rows of maize may be harvested for grain.

Cultivation and Yield.—It is not as necessary to prepare a deep seed bed for oats as for wheat, maize, etc. The oats are sown broadcast and covered with a disk harrow. Oats are sown in the northern states, as soon as possible in the spring and in the southern states, the winter varieties are sowed between October 1st and November 15th, while the spring sowing takes place there from January to March. The average yield per annum per acre of oats during the decade 1893–1902 was 27.8 bushels. Sixty to seventy-five bushels is considered a good yield, while in Canada 100 bushels have been produced to the acre. The center of oat cultivation in the United States is in Illinois, Iowa and Wisconsin. This shows a northward movement over the year 1850, when New York, Pennsylvania and Ohio were the principal oat-producing states.

Wheat (*Triticum*, several species).—As with all cultivated plants, which have been associated with the agricultural operations of man from very early days, there has been a discussion as to the origin of wheat. Recently Aaron Aaronsohn of the Agricultural Experiment Station in Palestine has discovered on Mount Hermon a wild wheat which has been named *Triticum hermonis* by O. F. Cook of the United States Department of Agriculture, who has studied in detail this interesting plant. What the relationship of this wild wheat is to the diverse types of cultivated wheats, it is too early to state, but this can be said, that it is doubtful whether all the cultivated types of wheat arose from a single wild species or from several wild species, more probably the latter is the true explanation. The cultivated wheats may be divided into two groups, as follows:

1. Naked wheats in which the grain comes free from the lemma and palet, and the rachis is tenacious. This group includes the durum wheat (*T. durum*), the Poulard wheat (*T. turgidum*), the club wheat (*T. compactum*), the common bread wheat (*T. æstivum*) and the Polish wheat (*T. polonicum*).

2. Spelt wheats, in which the grain remains attached to the lemma and palet and the rachis is fragile. This group includes the einkorn (*T. monococcum*), the emmer (*T. dicoccum*) and the spelt (*T. spelta*). The wheats of this group are nearest to the primitive condition, for it is generally agreed that the progenitor, or progenitors, of the cultivated forms had a fragile rachis, and this is borne out by the fact that the wheats cultivated in ancient times had fragile rachises, such as emmer, and by the fact that the wild species from Syria also agrees in this peculiarity. The *Triticum hermonis* is the *T. dicoccum dicoccoides*, a wild emmer, and this wild emmer is considered by Chodat to be the primitive form and he concludes that wheat is indigenous to Syria.

Description.—Wheat is an annual plant with fibrous roots and usually six-jointed stems, the upper or last internode being the spike-bearing one. The leaf of wheat is of the usual grass type with a split sheath and thin transparent ligule. The spikelets are arranged in a spike with an average of 15–20 fertile spikelets in a head (Fig. 72). The number of flowers in a spikelet varies from two to five. Each spikelet has two broad glumes at the base. The lemmas are awned, or beardless, that is awnless. There are three stamens and an ovary with two feathery styles. Two lodicules are present. In northern cold, or wet climates, close pollination is the rule with wheat, but in durum wheats cross pollination is habitual, and this seems to be the case with primitive wheats and those grown in hot, dry localities. The mature grain has a tuft of hairs, the brush, at the small (stigmatic) end of the kernel, and at the opposite end is found the embryo. A groove, or furrow, is found along the side of the grain facing the palet. In cross section, the following cell layers are distinguishable (1) ovary wall, or pericarp, several cells thick; (2) testa, two layers of cells; (3) tegmen; (4) aleurone layer often called the gluten layer; (5) starchy endosperm; (6) embryo. The bran layer includes the three outer layers viz., pericarp, testa and tegmen. The latter is represented by a

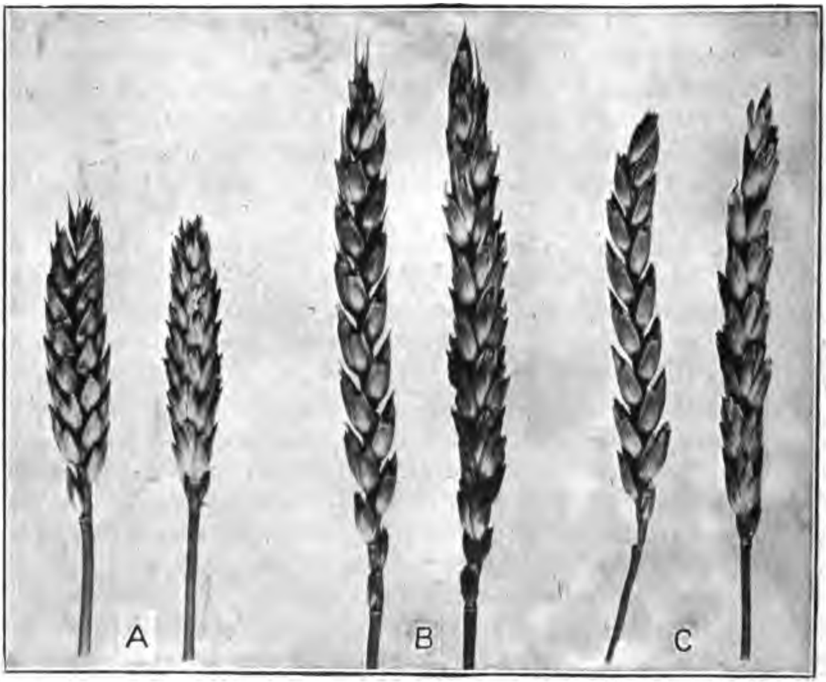


FIG. 72.—Heads of varieties of spring wheat grown at the Moro substation: *A*, Little Club; *B*, Pacific Bluestem; *C*, Karun. (*After Stephens, David E.: Experiments with Spring Cereals at the Eastern Oregon Dry-Farming Substation, Moro, Oregon. Bull.* 498, *U. S. Department of Agriculture*, 1917, *p.* 19.)

single layer of cells outside of the aleurone layer. In the undeveloped embryo, this tissue was large and prominent. The protein in the wheat varies from 8.1 per cent. to 17.2 per cent. with an average of 11.9 per cent. and there appear to be five kinds of wheat proteins: globulin, albumin, proteose, gliadin and glutenin, according to the researches of Osborne and Vorrhees. There are two kinds of wheat, hard and soft. The hard wheats have a horny character and are rich in protein. Such are the hard spring wheat (Fife and Bluestem), the hard winter wheat (Turkey and Krastov) and the durum wheat (Kubanka). Out of the durum wheats are manufactured macaroni, spaghetti and vermicelli.

Adaptation.—Wheat is best adapted to growth in moderately dry temperate climates. It is not grown in regions with a growing season less than ninety days, nor in regions having less than nine inches of annual rainfall. Wheat is grown on a wider range of soils, but the famous wheat soils of the world are of high fertility and of fine texture, such as silts, silt loams and clay loams, usually rich in humus. Black soils rich in nitrogen generally produce wheat with a higher gluten content, as those of the cherzonem of Russia, and the northwestern prairie soils of Canada and the United States. There are many varieties of wheat, some being winter annuals, sown in the fall and harvested in early summer, while others are sown in the spring and harvested usually ten to twenty days later than the winter varieties. The United States produces slightly less than one-fifth of the world's wheat and about one-half of the whole crop of the United States is produced in the North Central states west of the Mississippi River.

Rotation.—Rotations are best, although not always profitable, because continuous cropping with wheat reduces soil fertility. In winter wheat sections, wheat may follow corn, oats, potatoes or tobacco. Wheat requires a firm, fine and moist, seed-bed whether it be sown in the fall, or the spring. When wheat follows corn, potatoes, or tobacco, the ground should be plowed thoroughly for these crops in the spring of the year and the crops grown should receive thorough and regular cultivation, as long as possible. After the crop is harvested, double disking should put the ground in an ideal condition for the sowing of wheat. When winter wheat follows oats, the stubble should be plowed, as early, as possible. The results of Utah, North Dakota and Minnesota in plowing in fall and spring for spring wheat are only slightly in favor of the fall plowing, so far, as yield is concerned, but early fall plowing is generally advocated by these stations in the interest of weed and insect destruction, and more economical farm management. Spring plowing has given better results in Manitoba than fall plowing, while summer fallowing has given better results than either. The five course rotation of maize, oats, and wheat, each one year, and timothy and clover two years, is considered standard in many sections. The winter killing of winter wheat is often a source of great loss in the United States.

Cultivation and Yield.—The rate of seeding varies greatly in different wheat districts of the United States. East of the Mississippi River, two bushels of well-cleaned seed will give the best results. In the dry farming regions of the West, three pecks in the driest sections and six to eight pecks in the more humid sections are used. Wheat is usually harvested, when fully ripe. The straw should be yellow in color and the grain in hard dough, while on the Pacific Coast, it is allowed to stand a week, or two, after it is ripe and is then gathered with a combined harvester and thresher. Wheat should be shocked the same day it is cut. This prevents rapid drying and aids the more complete storage of starch in the grain from the plastic materials found in stem and leaves. The experience of last summer (1919) indicates that wheat should be hauled into the barn, as soon as possible, as a wet spell may completely destroy the crop by the sprouting of the wheat grains, while in shock. Threshing may then be done at a convenient time, the sooner the better, and the threshed grain should be stored in tight, clean granaries. The average yield of wheat in France is 20 bushels per acre. The yield of wheat in the United States in 1909, nineteen bushels per acre, was greatest in the regions receiving 30 to 35 inches of precipitation during that crop year. This yield of nineteen bushels per acre seems too low an average for a progressive agricultural country like the United States. The yield might be increased by giving up slip shod methods of cultivation and by growing improved varieties.

Barley (*Hordeum vulgare*).—Botanists recognize at least two species of barley with a number of varieties of each species. The two species are known to science as the six-rowed barley (*Hordeum vulgare*), and the two-rowed barley (*Hordeum distichon*). Koernicke believes that the prototype of the cultivated barleys is *Hordeum spontaneum*, a type nearly related to the *nutans* form of two-rowed barley. Rimpau considers the six-rowed bearded barley as the progenitor of all the types.

Winter barleys are susceptible to winter cold, even more than winter rye, or winter wheat, hence in the northern United States practically all the barley is sown in the spring. As a spring grown crop, it is cultivated in Alaska, as far north, as 65°N. latitude and up to an altitude of 7,500 feet in the Rocky mountains. At higher elevations, it is grown for hay in a variety known as "bald barley."

Description.—The barley plant is a summer, or a winter annual. The roots resemble those of the oat, and from the root system arise stems with five to seven joints occasionally an eighth. The inflorescence is a spike of spikelets with a strongly compressed rachis. The horizontal cushion, where the spikelets articulate, distinguishes barley from wheat and rye. There are three spikelets at each joint of the rachis. The lateral spikelets of each group of three are sometimes imperfect with the short branch, or rachilla, prolonged beyond the central spikelet as a bristle, but accommodated within the groove of the grain. Each spikelet is one-flowered. The glumes are narrow and awn-like forming an involucre-like enclosure of the spikelets. The lemma is broad and bears a long barbed awn. The palea is about, as long, as the lemma and has two ridges. The styles are short and the two lodicules are prominent. Self-pollination is the rule in the barleys, but occasional cross pollination occurs in the four-rowed and two-rowed nodding barleys. The mature kernel may be covered in the hulled barleys by the palet and lemma. These scales come loose in the naked barleys.

Barley is used principally in the preparation of malt in the brewing industries. Smaller quantities are ground and made into bread, while pearl barley is used in soups. Barley is a valuable feed for dairy cows, sheep, hogs and poultry.

Cultivation.—Barley should be sown, as soon, as danger from severe frosts are over, and the soil is sufficiently warm and dry to make a good seed bed. This date varies in the northern states from April 1 to May 15. In the humid regions, seeding is at the rate of 8 pecks to the acre and in drills six to eight inches apart. This method insures an even distribution of the seed. Barley, in seasons of drought is benefited by cultivation with a spike-toothed harrow, or weeder. In the Rocky Mountain states, considerable barley is grown under irrigation.

Barley ripens in the southern states from May 1 to June 1 and in the northern states during July and August. Care must be exercised to harvest barley at the right time, neither too early nor too late. A good index is the hardness of the grain which should just be dented with the finger nail. The crop is usually harvested with the binder, and if weather permits, the bundles should dry before being placed together in the shocks, which should be capped to protect the grain from heavy rains.

For small farms threshing from the stack is better than from the shock, as a better quality of grain is obtained. Care should be used in threshing as many grains will be cracked, if the concaves of the machine are set too close. After threshing, the grain should be carefully housed in dry bins.

The average yield of barley in the United States for the ten year period, 1900 to 1909, was 25.7 bushels per acre.

Rotations.—Great care should be exercised in the rotation of barley with other crops. Where barley replaces wheat in the rotation, the sequence of crops may be maize, barley and oats, each one year, or timothy and clover, one or more years. The land has thus had surface tillage the previous year and may have been manured. In some regions, barley replaces oats, when the rotation becomes maize, barley and wheat, each one year, followed with clover, or clover and timothy, one or two years.

Rye (*Secale cereale*).—The wild progenitor of the cultivated species is looked upon by botanists as *S. anatolicum*, one of the subspecies of *S. montanum*, which extends from Spain and Morocco to central Asia. The wild species is a perennial, but the cultivated form is an annual. The root system is a whorl of four primary roots, which extend into the soil to a depth of four to five feet. The stems of rye with five to six, rarely four- to seven-jointed are tougher, slenderer and larger than those of barley, oats and wheat. The rye inflorescence is a spike of spikelets. Each spikelet consists of three flowers, with the two lateral flowers perfect and maturing grains, while the middle floret is abortive. The glumes are narrow. The lemma is broad-keeled and bears a long terminal awn. The palet is thin, blunt and two-keeled. The lodicules are small and membranous. Three stamens are present in each perfect flower and a single pistil with two feathery styles. Rye is commonly cross-fertilized and in this respect is like maize, but unlike wheat, oats and barley. The mature grain is free from the lemma and palet. It is long, narrow and usually darker in color than wheat.

The structure of the rye caryopsis is like that of wheat, with somewhat similar layers of cell. Rye protein usually forms 6 to 12 per cent. of the grain. Gluten is present in the protein, hence, rye can be made into porous bread.

Rye is adapted to a colder, drier climate than wheat. It does well on poor, and sandy soils. Rye is fed to stock mixed with barley, maize, or oats. The straw is used for stable bedding, as a stuffing, and in the manufacture of paper, hats and other articles of straw.

Cultivation.—Spring rye is sometimes grown in the northern states, but it should give way to winter rye, where that grain crop will survive. About 96 per cent. of the world's rye is produced and consumed in Europe where in such states, as Germany, Holland, Russia, Belgium, Austria and

Hungary, it is of great importance. It is grown farther north than the other cereals. In the United States, rye is grown mostly in regions having a cool climate and sandy soils. About two-thirds of the rye grain produced in the United States is used as a cattle food and the other third formerly in the production of alcohol and alcoholic beverages.

Notwithstanding the fact, that rye will grow on poor soils, the crop responds to good soils and the application of fertilizers. When intended for a grain crop, it should be sown about September 1 in the northern states and in the latter half of November in the southern states. If used as a cover, pasture, or green manure crop, it should be planted two weeks to a month earlier than if grown for the grain. It should in all cases become well established before winter begins. Rye is best sown in drills 6 to 8 inches apart, using a regular grain drill and covering the seed one-half inch to two inches deep. The usual rate of seeding in the eastern states is about 6 pecks to the acre. Rye ripens about the middle of May in extreme northern Florida, and in the northern states between July 10 and July 25 being a few days earlier than wheat. The crop is cut and bound like wheat and the shocks are relatively high as the stems frequently reach a height of six feet. It is difficult, therefore, to harvest it with a self-binder. After the crop is well-cured in the shock, it should be stacked, or put under cover until threshing time. The grain is threshed out the same way as with wheat and the grains.

Rotation.—Ordinarily rye occupies the place assigned to wheat in a rotation. The Rhode Island station has practised a six-course rotation, as follows: first year, winter rye; second year, timothy, redtop and medium red clover; third year, grass; fourth year, grass and fifth year, maize; sixth year, potatoes. No stable manure was applied, but liberal supplies of fertilizers were used. Rye which is to be used as a green manure may be sown in the standing maize in September, or after maize is shocked, may be disked in without plowing. It is plowed into the soil the following spring. A rotation for Minnesota and suitable for other states in the same latitude is first year, rye (land fall plowed after crop); second year, barley (seeded to clover); third year, clover (second crop plowed under); fourth year, corn; fifth year, barley, or other grain. In some of the North Atlantic states, where rye straw has a high value, the following rotation may be followed successfully: first year, corn, with a heavy application of stable manure; second year, oats with acid phosphate; third year, rye with acid phosphate; fourth year, grass, seeded the year before with the rye. The ten-year (1907–1916) average yields in bushels per acre of rye for several of the southeastern United States have been as follows: Tennessee, 11.3; North Carolina, 9.9; Alabama, 11.2; Georgia, 9.3 and South Carolina, 10.1.

Rice (*Oryza sativa*).—This aquatic, or marsh grass is annual in habit and best adapted to growth under aquatic, marsh, or very wet soil conditions. There are upland varieties, but the lowland type is the one most generally grown in this country and abroad. Its roots are fibrous with the possible production of adventitious roots by the first, second and third nodes. Tillers are formed freely with the production of four, or five, hollow stems growing to a height of two to six feet. The leaf sheaths are split and the blades are from eight to twelve inches long and ¾ to 1 inch wide. The ligule is long and easily splits into two parts. The auricle is green, or white, and hairy.

The inflorescence is a panicle of spikelets. The spikelet is compressed laterally and has two scale-like, or bristle-like glumes with a small, minute, accessory glume beneath each. The lemma is compressed, membraneous and five-nerved. The palet is similar in size and texture. Awns may be absent, or present, on both lemma and palet. The lodicules are small, thick and fleshy. There are six functional stamens in each rice flower. The ovary is somewhat longer than broad, smooth and bears two styles and occasionally a rudimentary, third style. Self pollination is the rule with rice. The tip flowers of the spike open first. The rice caryopsis is inclosed by lemma and palet, or by the palet alone. Rice with the hull is known as paddy. Commercially "cleaned rice" is the hullless grain. Polished rice has recently come into prominence, because it has been found that individuals and persons feeding on an almost exclusive rice diet, as in India and the Philippines, suffer from a disease known as beri-beri. It has been recently discovered that beri-beri is a disease of malnutrition due to the absence of phosphates which reside in the surface of the rice kernel. A change of diet from polished rice to unpolished removes the cause of the disease.

Distribution and Soils.—Rice is the great food crop of the Chinese, Hindoos, Japanese and races of the Philippine islands and a grain of high quality has been produced in these regions. It is raised in northern Italy and in the southern United States outside of the great rice-producing countries. The bulk of the crop in the United States is raised in Louisiana and Texas. There is considerable acreage to rice in South Carolina and Georgia.

Rice is rarely raised north of that region in which the average summer temperature (June, July, August) is lower than 77°F., and in moist regions where lowland rice can be cultivated in delta, or alluvial lands, that can be inundated. The best soil for rice is a medium loam, containing about 50 per cent. of clay. This allows the presence of sufficient humus for the highest fertility without decreasing too much the compact nature of the soil. The rich, drift soils of the Louisiana and Texas prairies have shown a marvelous adaptation to rice. These soils are underlain with clay, so as to be retentive of water.

The rice lands of the United States comprise delta lands, inland marshes, alluvial lands and prairie lands. A large part of the rice grown in South Carolina and Georgia is produced on tidal deltas, and to some extent on inland marshes. In eastern Louisiana, rice is grown on low lands, which were once used as sugar plantations, also on the well-drained alluvial lands farther up the Mississippi River. In 1884 and 1885, a few farmers from the northwestern prairie states settled on the great southern prairie which extends along the coast from the parish of St. Mary in Louisiana to the Texas line. Wherever they found the prairie land sufficiently level with a creek nearby, which could be used to flood the land, they built small levees 12 to 24 inches high with an interior ditch 12 to 18 inches deep and form to five feet wide. Large crops of rice were raised by the adaptation of such agricultural machinery, as the gang plow, disk harrow, drill and broadcast seeder to the new conditions, but a set back came owing to the cheap construction of the levees and the advent of dry summers when the streams went dry. There are large areas devoted to raising rice in Arkansas where the rice fields vary from 10 to 40 acres plowed with tractors and gathered by harvesters. The yields run as high as 104 bushels, the average yield in 1919 being 60 bushels.

Cultivation.—The time of plowing is in the spring just before planting time and deep plowing should be practised as it places more food within reach of the roots of the growing rice. The amount of rice sown with a drill per acre varies in different sections and with different methods of sowing, from 1 to 3 bushels per acre should be used. After seeding just enough water is let on the field to saturate the ground. Flooding follows, when the rice is 6 to 8 inches tall, so as to prevent scalding of the plants. The depth of water that should be maintained from the first flooding until it is withdrawn for the harvest depends upon other conditions. If the growing crop thoroughly shades the land, just enough water to keep the soil saturated will do. To be on the safe side, the water should stand 3 to 6 inches deep and to prevent stagnation, there should be a constant inflow and outflow. Large fields impede complete drainage and uniform ripening. Hence, small fields are the best. At harvest time, the water is drawn off and as the soil is rarely sufficiently dry at this time heavy machinery cannot be used. The sickle is the implement commonly used in harvesting rice which is then bound, when it is dry, and shocked on the dry ground. Ten to twelve days will completely cure the grain. The primitive methods of flailing and treading out have given place to the use of the steam thresher. As the rice comes from the thresher it is known as "paddy," or "rough rice." It is passed through the mill to remove the hulls, or chaff, which are restored to the soil as a fertilizer, or are used as a mulch for garden and orchard. Rice straw is sweet and has an excellent flavor, much relished by stock, who eat it readily. As fashion demands rice with a fine gloss, it is usually polished, although its food value is diminished and an exclusive diet of polished rice induces a disease known as beri-beri.

Buckwheat (*Fagopyrum esculentum*).—The buckwheat is a member of the family *Polygonaceæ* and, therefore, not a true cereal, but for convenience, and because its fruit is grain-like, it is usually considered along with the grain-producing plants. There are two other species of buckwheat occasionally cultivated in this country and in Asia.

Description.—The roots of the buckwheat consist of a true primary roots with several branches. The stem ascends to a height of two to three feet, and bears alternate, triangular, heart-shaped, or halberd-shaped leaves with semicylindrical sheaths or ocrea. The white flowers are borne in corymbose racemes and are dimorphic with long styles and short styles respectively which prevents self-pollination. The sepals which alone are present bear eight, honey-bearing, yellow glands interposed between the eight stamens. The ovary is surmounted by three styles and the ripe achene is three-angled, smooth and shining. The grain incloses a single seed with a curved, dicotyledonous embryo surrounded by a starchy endosperm.

Buckwheat is adapted to temperate climates with cool, moderately moist summers. The fruit does not set properly in dry, hot weather. It does well on poor soils. The principal use of buckwheat is in the manufacture of pancake flour. The whole fruit is sometimes fed to cattle, hogs and poultry. The middlings (hulls mixed with bran) are utilized in the feeding of stock. The honey made from the nectar of buckwheat by honey-bees has a high reputation for flavor. The plant is sometimes used as a green manure, being rich in ash and nitrogen.

Cultivation.—The seed bed is prepared immediately preceeding the sowing of buckwheat by plowing and harrowing the soil. The farmers of northern Pennsylvania have a saying that buckwheat should be planted when the chestnut tree comes into flower, but the date of seeding varies from May 1st to August 1st, the preferred time being the middle of June to the middle of July. The plant comes into flower early and continues to bloom until frost comes. Buckwheat is usually harvested when the first achenes are mature, which is usually in September. Much is still harvested with a cradle. The plants are not bound, but are set up in shocks like maize fodder and threshed, as soon, as dry. The yield per acre varies from five to fifty bushels. An average of twenty to twenty-five bushels is considered a satisfactory yield.

Bibliography

The following items are arranged according to the cereal plants discussed above without any attempt at making the list complete.

Maize

Arctowski, Henry K.: Studies on Climate and Crops. Corn Crops in the United States. Bulletin American Geographical Society, xliv, 745–760, October, 1912.

Bowman, M. L. and Crossley, B. W.: Corn Growing, Judging, Breeding, Feeding, Marketing. Ames, Iowa, Second Edition, 1911.

Brand, Charles J.: The Utilization of Crop Plants in Paper Making. Yearbook, U. S. Department of Agriculture, 1910, 329–340; Crop Plants for Paper Making, Circular 82, Bureau of Plant Industry, 1911.

Cates, H. R.: Farm Practice in the Cultivation of Corn. Bulletin 320, U. S. Department of Agriculture, 1916.

Chilcott, E. C., Cole, J. S. and Burr, W. W.: Corn in the Great Plains Area. Bulletin 219, U. S. Department of Agriculture, 1915.

Collins, G. N.: A New Type of Indian Corn from China. Bulletin 161, Bureau of Plant Industry, U. S. Department of Agriculture, 1909; The Importance of Broad Breeding in Corn. Bulletin 141, Part IV, Bureau of Plant Industry, 1909; Apogamy in the Maize Plant. Contributions, U. S. National Herbarium, xii, 453–455, 1909; Increased Yields of Corn from Hybrid Seed. Yearbook, U. S. Department of Agriculture, 1910, 319–328; The Value of First Generation Hybrids in Corn. Bulletin 191, Bureau of Plant Industry, U. S. Department of Agriculture, 1910; The Origin of Maize. Journal Washington Academy of Science, II, 520–

530, December, 1912; A Variety of Maize with Silks Maturing before the Tassels. Circular 107, Bureau of Plant Industry, 1913; Correlated Characters in Maize Breeding. Journal Agricultural Research, vi, 435–453, June, 1916; Hybrids of Zea ramosa and Zea tunicata. Journal Agricultural Research, ix, 383–395, June, 1911; Breeding Sweet Corn Resistant to the Earworm. Journal Agricultural Research, xii, 549–572; Structure of the Maize Ear as Indicated in Zea-Euchlaena Hybrids. Journal Agricultural Research, xvii, 127–135, June, 1919; A Fossil Ear of Maize. Journal of Heredity, x, 170–172.

Duvel, J. W. T.: Grades for Commercial Corn. Bulletin 168, U. S. Department of Agriculture, 1915.

Finch, V. C. and Baker, O. E.: Geography of the World's Agriculture. U. S. Department of Agriculture, 1917.

Freeman, W. G. and Chandler, S. E.: The World's Commercial Products. Boston, Ginn and Company, 1911.

Gardner, Frank D.: Successful Farming. Philadelphia, John C. Winston Company, 1916.

Gernert, W. B.: The Analysis of Characters in Corn and Their Behavior in Transmission. Thesis Graduate School, University of Illinois, Champaign, 1912.

Harshberger, John W.: Maize: A Botanical and Economic Study. Contributions from the Botanical Laboratory, University of Pennsylvania, I, 75–202, 1893; El Maiz Estudio Botanico y Economico, Secretaria de Fomento, Mexico, 1894 (translation of the above); Fertile Crosses between Teosinte and Maize. Garden and Forest, ix, 522, 1896; Notes on the Hybrid of Maize and Teosinte. Garden and Forest, x, 48, 1897; A Study of the Fertile Hybrids produced by Crossing Teosinte and Maize. Contributions from the Botanical Laboratory, University of Pennsylvania, II, 231; Maize in Cyclopedia of American Agriculture, II, 398–402, 1908; An Unusual Form of Maize. Proceedings of the Delaware County Institute of Science, vi, 49–53, January, 1911.

Hartley, C. P.: The Production of Good Seed Corn. Farmers' Bulletin 229, U. S. Department of Agriculture, 1905; Harvesting and Storing Corn. Farmers' Bulletin 313, 1907; Corn Cultivation. Farmers' Bulletin, 414, 1910; Seed Corn. Farmers' Bulletin, 415, 1910; with Zook, L. L.: Corn Growing under Droughty Conditions. Farmers' Bulletin, 773, 1916.

Hayes, H. K.: Inheritance in Corn. Report Connecticut Agricultural Experiment Station, 1911, 407–425.

Hayes, H. K. and East, E. M.: Inheritance in Maize. Bulletin 167, The Connecticut Agricultural Experiment Station, New Haven, April, 1911; Further Experiments on Inheritance in Maize. Bulletin 188, do., September, 1915.

Hopkins, Cyril G.: The Chemistry of the Corn Kernel. Bulletin 53, University of Illinois Agricultural Experiment Station, Urbana, July, 1898; Methods in Corn Breeding, Bulletin 82, do., December, 1902; The Structure of the Corn Kernel and the Composition of its Different Parts. Bulletin 87, do., August, 1903.

Hughes, H. D.: The Germination Test of Seed Corn. Bulletin 135, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa, February, 1913.

HUME, ALBERT N.: The Testing of Corn for Seed. Bulletin 96, University of Illinois, Agricultural Experiment Station, Urbana, November, 1904.

HUNT, THOMAS F.: The Cereals of America. New York, Orange Judd Company, 1912; Corn Growing in the East. Bulletin 116, The Pennsylvania State College Agricultural Experiment Station, April, 1912.

JONES, W. J. and HUSTON, H. A.: Composition of Maize at Various Stages of its Growth. Bulletin 175, Purdue University Agricultural Experiment Station, Lafayette, Indiana, 1914.

KEMPTON, J. H.: Inheritance of Waxy Endosperm in Maize. Bulletin 754, U. S. Department of Agriculture, 1919.

KYLE, C. H.: Corn Culture in the Southeastern States. Farmers' Bulletin 729, U. S. Department of Agriculture, 1916.

LINDSEY, J. B.: The Feeding Value of Corn Stover. Yearbook of the U. S. Department of Agriculture, 1896, 353–360.

LINDSTROM, E. W.: Chlorophyll Inheritance in Maize. Memoir 13, Cornell University, Agricultural Experiment Station, Ithaca, August, 1918.

MONTGOMERY, E. G.: What is an Ear of Corn? Popular Science Monthly, January, 1906, pages 55–62; with KIESSELBACH, T. A.: Studies in the Water Requirements of Corn. Bulletin 128, Agricultural Experiment Station of Nebraska, Lincoln, 1912.

MYRICK, HERBERT: The Book of Corn. New York, Orange Judd Company, 1904.

PEARL, RAYMOND and SURFACE, FRANK M.: Experiments in Breeding Sweet Corn. Annual Report of the Maine Agricultural Experiment Station, 1910, 249–307.

PEARL, RAYMOND and BARTLETT, JAMES M.: The Mendelian Inheritance of Certain Chemical Characters in Maize. Zeitschrift für induktive Abstammunngs und Vererbungslehre, 1911, Bd. vi, Heft 1 u. 2, pages 1–28.

PLUMB, C. S.: Indian Corn Culture. Chicago, Breeder's Gazette Print, 1903.

ROBBINS, WILFRED W.: The Botany of Crop Plants. Philadelphia, P. Blakiston's Son & Co., 1917.

SARGENT, FREDERICK LEROY: Corn Plants, their Uses and Ways of Life. Boston and New York, Houghton, Mifflin and Company, 1899.

SCOFIELD, CARL S.: The Commercial Grading of Corn. Bulletin 4, Bureau of Plant Industry, 1903.

SHERARD, SAM H.: Corn Culture in the Philippine Islands. Bulletin 23, Bureau of Agriculture, Philippine Islands, 1912.

SHULL, GEORGE H.: The Genotypes of Maize. The American Naturalist, 1911, 234–252.

STURTEVANT, E. L.: Varieties of Corn. Bulletin 57, Office of the Experiment Stations, U. S. Department of Agriculture, 1899.

TRACY, S. M.: Corn Culture in the South. Farmers' Bulletin 81, U. S. Department of Agriculture, 1898.

WEATHERWAX, PAUL: Morphology of the Flowers of Zea mays. Bulletin Torrey Botanical Club, 43, 127–144, April, 1916; The Development of the Spikelets of Zea mays, do, 43, 483–496, October, 1917; The Evolution of Maize, do, 45, 309–342, September, 1918; Gametogenesis and Fecundation in Zea mays as the Basis of Xenia and Heredity in the Endosperm, do, 46, 73–90, March, 1919.

WEBBER, HERBERT J.: Xenia, or the Immediate Effect of Pollen in Maize. Bulletin 22, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture, 1900.

WILSON, ALEXANDER STEPHEN: Fertilization of Cereals. Gardeners' Chronicle, I, 340–341 (March 14, 1874).

WING, DE WITT C.: The Improvement of Corn in Pennsylvania. Bulletin 133, Department of Agriculture of Pennsylvania, 1904.

WISSLER, CLARK: Indian Corn as a World Food. American Museum Journal, January, 1918, 25–29.

WOODS, CHARLES D.: Food Value of Corn and Corn Products. Farmers' Bulletin 298, U. S. Department of Agriculture, 1907.

ZOOK, L. L.: Tests of Corn Varieties on the Great Plains. Bulletin 307, U. S. Department of Agriculture, 1915.

OATS

CARLETON, MARK ALFRED: Ten Years Experience with the Swedish Select Oat. Bulletin 182, Bureau of Plant Industry, U. S. Department of Agriculture, 1910; The Small Grains. New York, The Macmillan Company, 1916.

CHILCOTT, E. C.: Oats in the Great Plains Area. Relation of Cultural Methods to Production. Bulletin 218, U. S. Department of Agriculture, 1915.

ETHERIDGE, W. C.: A Classification of the Varieties of Cultivated Oats. Memoir 10, Cornell University Agricultural Experiment Station, October, 1916 with 33 text figures and 22 plates in color.

FINCH, U. C. and BAKER, O. E.: Geography of the World's Agriculture. U. S. Department of Agriculture, 1917.

FREEMAN, W. G. and CHANDLER, S. E.: The World's Commercial Products. Boston, Ginn and Company, 1911.

GARDNER, FRANK D.: Successful Farming. Philadelphia, John C. Winston Company, 1916.

HUNT, THOMAS J.: The Cereals in America. New York, Orange Judd Company, 1912.

ROBBINS, WILFRED W.: The Botany of Crop Plants. Philadelphia, P. Blakiston's Son & Co., 1917.

SMITH, J. RUSSELL: The World's Food Resources. New York, Henry Holt and Company, 1919.

WARBURTON, C. W.: Spring Oat Production. Farmers' Bulletin 892, U. S. Department of Agriculture, 1910; Oats: Distribution and Uses. Farmers' Bulletin 420, 1910; Oats: Growing the Crop. Farmers' Bulletin 424, 1910; Winter Oats for the South. Farmers' Bulletin 436, 1911.

WHEAT

BALL, CARLETON R.: Experiments with Marquis Wheat. Bulletin 400, U. S. Department of Agriculture, 1916.

BALL, CARLETON R. and CLARK, ALLEN J.: Experiments with Durum Wheat. Bulletin 618, U. S. Department of Agriculture, 1918.

BLANCHARD, HENRY F.: Improvement of the Wheat Crop in California. Bulletin 178, Bureau of Plant Industry, U. S. Department of Agriculture, 1910.

CARLETON, MARK ALFRED: Macaroni Wheats. Bulletin 3, Bureau of Plant Industry, U. S. Department of Agriculture, 1901; Winter Emmer. Farmers' Bulletin 466, 1911; with CHAMBERLAIN, JOSEPH S.: The Commercial Status of Durum Wheat. Bulletin 70, Bureau of Plant Industry, U. S. Department of Agriculture, 1904.

CHILCOTT, E. C.: Spring Wheat in the Great Plains Area. Bulletin 214, U. S. Department of Agriculture, 1915; with COLE, JOHN S.: Growing Winter Wheat on the Great Plains. Farmers' Bulletin 895, 1917; and COLE, JOHN S. and KUSKA, J. B.: Winter Wheat in the Great Plains Area. Bulletin 595, U. S. Department of Agriculture, 1917.

COOK, O. F.: Wild Wheat in Palestine. Bulletin 274, Bureau of Plant Industry, U. S. Department of Agriculture, 1913.

EDGAR, WILLIAM C.: The Story of a Grain of Wheat. New York, D. Appleton and Company, 1903.

HUNTER, BYRON: Dry Farming for Better Wheat Yields. The Columbia and Snake River Basins. Farmers' Bulletin 104, 1919.

LEIGHTY, CLYDE E.: The Culture of Winter Wheat in the Eastern United States. Farmers' Bulletin 596, 1914; Winter-wheat Varieties for the Eastern United States. Farmers' Bulletin 616, 1914.

LYON, T. L.: Improving the Quality of Wheat. Bulletin 78, Bureau of Plant Industry, U. S. Department of Agriculture, 1905.

SALMON, CECIL and CLARK, J. ALLEN: Durum Wheat. Farmers' Bulletin 534, 1913.

SCOFIELD, CARL S.: The Algerian Durum Wheats. Bulletin 7, Bureau of Plant Industry, U. S. Department of Agriculture, 1902; The Description of Wheat Varieties, Bulletin 47, Bureau of Plant Industry, 1903.

THOMAS, L. M.: A Comparison of Several Classes of American Wheats and a Consideration of Some Factors Influencing Quality. Bulletin 557, U. S. Department of Agriculture, 1917; Characteristics and Quality of Montana-grown Wheat. Bulletin 522, U. S. Department of Agriculture, 1917.

BARLEY

CHILCOTT, E. C., COLE, J. S. and BURR, W. W.: Barley in the Great Plains Area. Bulletin 222, U. S. Department of Agriculture, 1915.

DERR, H. B.: Barley Culture in the Southern States. Farmers' Bulletin 427, U. S. Department of Agriculture, 1910; Barley: Growing the Crop. Farmers' Bulletin 443, 1911; Winter Barley. Farmers' Bulletin 518, 1912.

HARLAN, HARRY V.: The Identification of Varieties of Barley. Bulletin 622, U. S. Department of Agriculture, 1918; Cultivation and Utilization of Barley. Farmers' Bulletin 968, 1918.

MANN, ALBERT: Morphology of the Barley Grain with Reference to its Enzym-secreting Areas. Bulletin 183, U. S. Department of Agriculture, 1915.

RYE

CARLETON, MARK ALFRED: Russian Cereals Adapted for Cultivation in the United States. Bulletin 23, Division of Botany, U. S. Department of Agriculture, 1900.

LEIGHTY, CLYDE E.: Culture of Rye in the Eastern Half of the United States. Farmers' Bulletin 756, U. S. Department of Agriculture, 1916; Rye Growing in the Southeastern States. Farmers' Bulletin 894, 1917.

Rice

Chambliss, Charles E.: The Culture of Rice in California. Farmers' Bulletin 688, U. S. Department of Agriculture, 1915; Prairie Rice Culture in the United States. Farmers' Bulletin 1092, 1920.

Freeman, W. G. and Chandler, S. E.: The World's Commercial Products. Boston, Ginn and Co., 1911.

Knapp, S. A.: Rice Culture in the United States. Farmers' Bulletin 110, 1900; Rice Culture. Farmers' Bulletin 417, 1910.

Wise, F. B. and Broomell, A. W.: The Milling of Rice and Its Mechanical and Chemical Effect upon the Grain. Bulletin 330, U. S. Department of Agriculture, 1916.

Buckwheat

Gardner, Frank D.: Successful Farming. Philadelphia, The John C. Winston Company, 1916.

Hunt, Thomas F.: The Cereals in America. New York, Orange Judd Company, 1912.

Leighty, Clyde E.: Buckwheat. Farmers' Bulletin 1062, U. S. Department of Agriculture, 1919.

Robbins, Wilfred W.: The Botany of Crop Plants. Philadelphia, P. Blakiston's Son & Co., 1917.

Laboratory Work

Suggestions to Teachers.—Plants with inflorescences and flowers of oats, wheat, barley, rye and rice should be dried in the sun and then tied in bundles of a hundred, or more. The inflorescences should be wrapped in stiff paper for preservation. Ears of maize should be dried and kept in tin boxes and the tassel with the unopened flowers should be preserved in alcohol. Inflorescences of all the above cereals should be kept in alcohol. Fruits of buckwheat may be preserved in the dry state and whole plants with flowers in alcohol. Suggestions for the conduction of laboratory work with the cereals will be found in Hunt, Harris F.: The Cereals in America, 1912, and to that book the teacher is referred.

Laboratory Exercises

1. Describe in detail, following the outline provided by the teacher, each of the cereal plants: corn, oats, wheat, barley, rye, rice and buckwheat. This can be done in any part of the civilized world, including China and Japan.

2. Draw and study the caryopses of corn, oats, wheat, barley, rye and rice.

3. Section the same and apply the iodine test in order to locate the position of the reserve food and the embryo.

4. Study microscopic sections of wheat kernel in order to locate the aleurone layer. This can be pursued with the other grains, if time permits.

5. Draw and study the early stages of germination of the above fruits and determine the different parts of the seedlings, as they unfold, or show sequential development.

6. With such a book for reference, as the "Manual of Corn Judging," by A. D. Shamel, New York, Orange Judd Company (1903), learn to judge the various ears of corn kept for laboratory work in corn judging.

CHAPTER 14

GENERAL CHARACTERISTICS OF THE LEGUMINOSÆ

This family of approximately 487 genera and 10,782 species of plants is next to the grass family the most important one economically speaking in the vegetable kingdom. It includes herbs (clovers), shrubs (clammy locust) and trees (mesquite, honey locust).

Roots.—Their roots are both primary and secondary upon which are found nodules, or tubercles, of varying size. These tubercles are inhabited by a bacterium, *Pseudomonas radicicola*, which is active in their formation. It is believed that this organism associated in the galls or tubercles with the leguminous plants is capable of utilizing free atmospheric nitrogen, and in some way is able to transform this inorganic nitrogen into organic nitrogen, which is absorbed by the higher green leguminous plants.[1]

Stems.—The stems of the herbaceous plants of the family are annual (peas), biennial (sweet clover) and perennial (alfalfa). Sometimes twining stems are met with in the herbaceous stems (bean), or in the woody stems (*Wistaria*), when they are known as lianes. Occasionally, as in the genus *Lathyrus*, the stems may be winged.

Leaves.—The leaves are alternate and stipulate. The stipules, as in the pea, may be enlarged and leaf-like, in other cases (black locust), they may be converted into spines. The leaves are simple (*Chorizema*), or compound, palmately, or pinnately compound. The palmately compound leaf may be trifoliate of three leaflets, or as in lupine, there may be as many as seven to eleven leaflets. The pinnately compound leaves may be trifoliate with the middle leaflet provided with a longer petiolule than the other two, or it may have more than three leaflets, up to many, with a terminal leaflet (odd, or imparipinnate), or with a pair of terminal leaflets (paripinnate), or ending in a simple, or a branched, tendril (tendriliform, or cirrhiferous). The bases of the leaflets and the base of the common petiole have swellings known as pulvini. The presence of these pulvini enables the leaflets to assume nyctitropic and hot-sun posi-

[1] See Chapter 16.

tions, and in the sensitive plants, represented by *Mimosa pudica,* a stimulation of a terminal leaflet, for example, causes the movement of all of the leaflets of the compound leaf, if the stimuli are sufficiently strong.

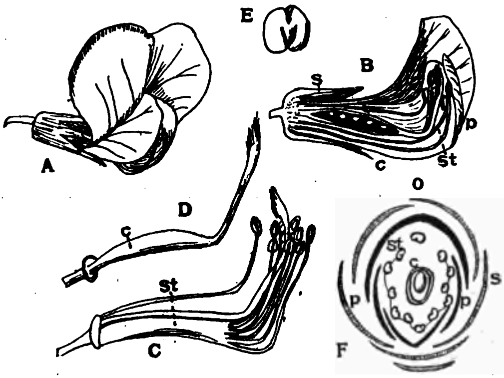


FIG. 73.—Details of Pea (*Pisum sativum*). *A*, Flower; *B*, Longitudinal section of flower showing ovary, diadelphous stamens, etc.; *C*, diadelphous stamens and style with stigma; *D*, pistil of pea flower; *E*, seed deprived of its coats; *F*, floral diagram; *s* = sepals; *p* = petals; *st* = stamens; *c* = carpel.

The movement in the sensitive plants of this family is due to the movement of water from the lower to the upper side of the pulvinus, so that the whole

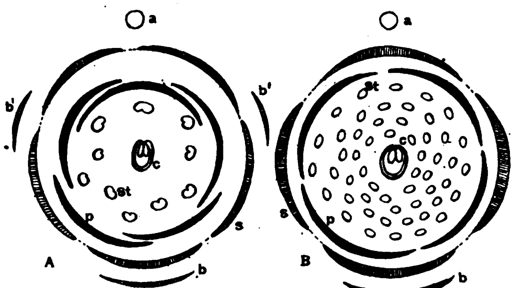


FIG. 74.—*A*, Floral diagram of red bud (*Cercis canadensis*) of the sub family CAESALPINOIDEÆ; *B*, Diagram of wattle (*Acacia latifolia*) of the subfamily MIMOSOIDEÆ; *b* = bract; *b′* = bractlet; *s* = sepals; *p* = petals; *st* = stamens; *c* = carpel; *a* = axis.

leaf drops through a considerable angle. The telegraph plant (*Desmodium gyrans*) shows spontaneous movements of its leaflets upwards and downwards, changing their position sometimes by as much as 180°.

Inflorescence and Flowers.—The inflorescence is a raceme (*golden chain*), an umbel, a spike-like raceme, or a head (capitulum), as in the clovers. The flowers are regular (*Mimosa*), or mostly irregular with three to five sepals, and usually five petals with perigynous insertion. As there are three types of flowers, their structure may be described by reference to the three subfamilies, viz., *Papilionoideæ* (Fig. 73) *Cæsalpinoideæ* and *Mimosoideæ* (Fig. 74). The papilionaceous flowers are irregular with three to five sepals and five petals, the posterior one of which is called the vexillum, standard, or flag petal; two lateral petals, the wings, or alæ, and two interior petals united by their edges to form the keel, or carina (Figs. 73 and 75). The stamens are perigynous in insertion, ten in number, monadelphous, diadelphous, or occasionally distinct. The standard incloses the lateral petals in this subfamily, so that the estivation is known as the vexillary type. The cæsalpiniaceous flowers are irregular, or regular, with the odd petal, or standard, inclosed by the two lateral petals, or wings, and the stamens are generally ten in number and distinct. The mimosaceous flower is regular with three to five petals, which are valvate in the bud and the stamens are numerous, or indefinite, and distinct (see floral diagrams in figures 73 and 74.)

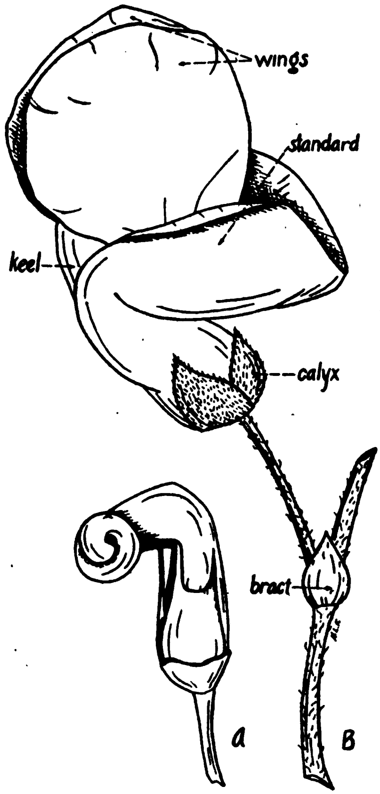


FIG. 75.—Common kidney bean (*Phaseolus vulgaris*). *A*, spiral keel; *B*. entire flower. ×2½. (*Robbins*.)

Ovary and Fruit.—The ovary is superior in all three subfamilies. It is apocarpous with one carpel. It is one-celled with parietal placenta. The style may be long or short, bent, or straight (Fig. 76). The fruit is a pod, or legume, occasionally a transversely divided pod, known as the loment. Each division of the loment is usually one-seeded. The seeds are large or small and exalbuminous that is, with the reserve food stored in the seed leaves, or cotyledons, which become fleshy as a consequence.

Economic Plants.—The economic plants of the family are numerous and their uses are manifold, on account of the presence of starch and protein, as reserve materials in their seeds and other parts. Many leguminous plants are used as human food. Such are the peas (*Pisum*), beans (*Phaseolus*), broad bean (*Vicia*), soy (*Soja*), peanut (*Arachis*), lentil (*Lens*), whose seeds are used in various ways, and the pods of carob (*Ceratonia*) and tamarind (*Tamarindus*), are eaten by man. The fodder plants of the family include the clovers (*Trifolium*), alfalfa (*Medicago*) sweet clover (*Melilotus*) sainfoin (*Onobrychis*), serradella (*Ornithopus*), cowpea (*Vigna*)

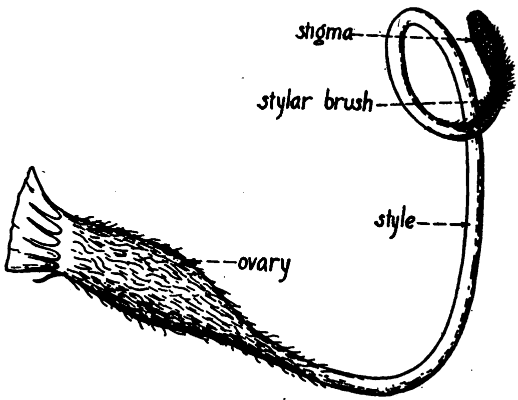


FIG. 76.—Pistil of flower of common bean (*Phaseolus vulgaris*). (*Robbins after Knuth.*)

Timber Trees.—The trees of the family useful for timber and structural wood are logwood (*Hæmatoxylon campechianum*), black locust (*Robinia pseudacacia*), mesquite (*Prosopis juliflora*), rosewood (*Dalbergia latifolia*) and others. The plants, which are capable of producing commercial fibers, are *Crotalaria juncea*, *Sesbania cannabina*, *S. esculenta*, *Aeschynomene spinulosa*, *Erythrina suberosa*, etc. A considerable number of plants yield gums, such as, copaiva balsams (*Copaifera*), balsam of tolu (*Toluifera*), copal (*Hymenæa*), gum arabic (*Acacia*), gum kino (*Pterocarpus*). As dye-yielding plants may be mentioned species of *Genista* (yellow), *Indigofera* (blue), *Mucuna pruriens*, (black), *Hæmatoxylon* (purple).

Drugs.—The important drugs of this family are abrus (*Abrus precatorius*), gum arabic (*Acacia arabica*), gum senegal (*Acacia senegal*), balsam of Peru (*Toluifera Pereiræ*), wild indigo (*Baptisia tinctoria*), purging cassia (*Cassia fistula*), copaiba (*Copaiba oblongifolia, C. officinalis*), fenugreek (*Trigonella Foeno-groecum*), liquorice (*Glycyrrhiza glabra*), indigo (*Indigofera tinctoria*), physostigma (*Physostigma venenosum*), senna (*Acacia senna*), tamarind (*Tamarindus indicus*) and tragacanth (*Astragalus gummifer*). The poisonous plants of the family, such as the loco weeds, have been described in a previous chapter.

Garden Plants.—A large number of beautiful garden plants belong to this family. Such are the sweet pea (*Lathyrus odoratus*), genista (*Cytisus canariensis*), lupine (*Lupinus perennis*, etc), wistaria (*Wistaria sinensis*), black locust (*Robinia pseudacacia*), flamboyant tree (*Poinciana regia*), acacia (*Acacia*), etc.

Bibliography

ENGLER, A. and PRANTL, K.: Die natürlichen Pflanzenfamilien III, Teil, 3 Abteilung, 1894, 70–384.

GRAY, ASA, revised by ROBINSON, B. H. and FERNALD, M. L.: A Handbook of the Flowering Plants and Ferns of the Central and Northeastern United States and Adjacent Canada. (Seventh Edition), 1908, 499–530.

HARE, HOBART A., CASPARI, CHARLES and RUSBY, H. H.: The National Standard Dispensatory. (Eighth Revision), 1905.

KRAEMER, HENRY: Applied and Economic Botany. 1914, 567–577.

LE MAOUT, EMM. and DECAISNE, J.: A General System of Botany, Descriptive and Analytical. London, 1873, 364–374.

ROBBINS, WILFRED W.: The Botany of Crop Plants. Philadelphia, P. Blakiston's Son & Co., 1917, 413–468.

WARMING, Eug. transl. by POTTER, M. C.: A Handbook of Systematic Botany. 1895, 466–475.

WETTSTEIN, RICHARD R. V.: Handbuch der Systematischen Botanik. (Zweite Auflage), 1911, 656–666.

Laboratory Works

Suggestion to Teachers.—During the winter months when this family will be studied probably by the class in botany, only a relatively few plants will be available. They are sweet peas (*Lathyrus odoratus*), genista (*Cytisus canariensis*), chorizeme (*Chorizema ilicifolia*), and if large greenhouses are conveniently located, several species of *Acacia* and *Mimosa* may be utilized. In California and the west lupines (*Lupinus*), clovers (*Trifolium*) and alfalfa (*Medicago*), etc., can be had. Flowers of a number of wild and cultivated species of this family, as locally obtainable, may be kept in alcohol.

Dried pods of honey locust, mesquite, Kentucky coffee tree, etc., may be kept, and of course bean, pea, broad bean, vetch, lentil, cowpea, clover and alfalfa seeds are always available for class use, and may be grown in flats or pots in the laboratory greenhouse, or window. If the work is undertaken in spring and summer, out-of-door species can be had.

Laboratory Exercises

1. Study the morphology of the roots, stem, leaves and flowers of the sweet pea and compare with the flowers of two other selected papilionaceous types. These may be compared with alcoholic *Cercis* (Cæsalpinioideæ) and *Acacia* (Mimosoideæ) Other members of the family can be selected according to geographic location.

2. Study the dried and swollen seeds of pea, bean, broad bean and clovers. Draw and then identify the parts of the embryos.

3. Scrape out some of the reserve food materials on a slide, examine the starch grains and then stain with iodine solution.

4. A study of the nodules has been reserved for a later chapter.

CHAPTER 15

THE FORAGE PLANTS OF THE FAMILY LEGUMINOSÆ

There are a large number of available plants of this family, which can be used for forage, but the majority of them although they have been introduced and tried have not been tested sufficiently to warrant their general cultivation. Such are the sainfoin (*Onobrychis viciaefolia*), Egyptian clover (*Trifolium alexandrinum*), bur clover (*Medicago arabica*), yellow clover (*Medicago lupulina*), Japan clover (*Lespedeza striata*), Florida clover (*Desmodium tortuosum*), purple vetch (*Vicia atropurpurea*), and velvet bean (*Mucuna utilis*). There are however, a number of extremely important species which will be discussed in the pages which follow. They are alfalfa, red clover, alsike clover, crimson clover, white clover, sweet clover, Canadian field pea, cowpea, soy, hairy-vetch and the peanut. These plants are not only useful in the amount of forage that they yield, but because they are used also as green manures to enrich the soil and in their growth to crowd out weeds.

Alfalfa (*Medicago sativa*).—The original home of this plant appears to have been southwest of central Asia having been cultivated by the Persians, who carried it with them in the invasion of Greece about 490 B.C. It was cultivated by the Romans at an early date for Varro in his "Rerum Rusticarum Libri Tres," Book I, Chapter XLII speaks of the plant. "You should take care not to plant alfalfa in soil which is neither too dry or half wet, but in good order. The authorities say that if the soil is in proper condition a *modius* (peck) and a half of alfalfa seed will suffice to sow a *jugerum* of land. This seed is sowed broad-cast on the land like grass and grain." Although we have used the name alfalfa in the above account of the plant introduced into Italy from Greece, yet the name is a Moorish one introduced into Spain with the Moors in the eighth century, whence it reached Mexico and South America with the Spaniards. The name came into current use in California, when the plant was introduced across the border.

Description.—The alfalfa is a perennial member of the leguminous family with deep growing roots penetrating usually to about nine feet, but under exceptional conditions to a depth of forty and even sixty feet. The aerial stems are ascending, or erect, and increase in number with successive cuttings, so that a single root system may give rise to as many as one hundred stems, although usually the number varies from twenty to

FIG. 77.—Alfalfa, or lucern (*Medicago sativa*): *a*, *b*, seed pod, side and end view: *c*, seeds, enlarged. (*After Smith, Jared G.: Meadows and Pastures. Farmers' Bulletin* 66, 1904, *p.* 27.)

fifty. Three cuttings are made yearly throughout the alfalfa-growing regions of the United States, although in the Imperial Valley, California, as many as nine cuttings have been made in one year. The leaves are with a serrate margin (Fig. 77). The inflorescence is a short, dense raceme with purple, papilionaceous flowers. The color may at times be green, blue or yellow. The calyx teeth are longer than the so called calyx tube. The standard exceeds the wings in length, which are longer than the keel.

The staminal tube of ten, diadelphous stamens is held in a state of tension by two opposite lateral projections arising from the inside of the keel. This mechanism brings about the explosive discharge of the pollen, when the staminal tube is released, and the pistil and stamen snap up against the standard and this process is known as "tripping." Bumblebees and leaf-cutting bees are usually the "trippers" of alfalfa flowers (Fig. 78). Insect visitation induces cross pollination, but automatic release of the floral parts by the action of humidity and temperatures results in self pollination. An abundance of insect life usually increases the output of seeds. Other conditions of climate and cultivation also influence seed production. The alfalfa fruit is a spirally coiled pod with two or three coats. Each pod contains from one to eight kidney-shaped seeds about ⅛ inch long, which, retain their vitality for many years (Fig. 77).

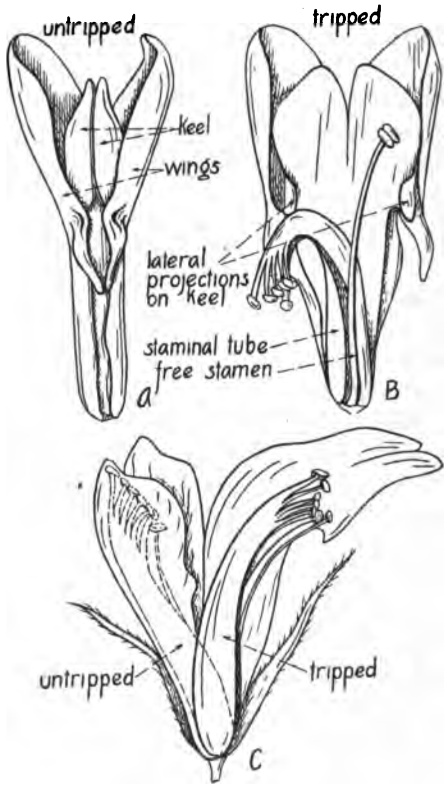


FIG. 78.—Pollination of alfalfa. *A*, flower untripped with calyx and standard removed; *B*, same tripped; *C*, position of staminal tube untripped and tripped. (*Robbins after U. S. Dept. Agri.*)

Varieties.—There are a considerable number of varieties of alfalfa in cultivation. There is a hardy variety suitable for growth in the cold northwest known as Grimm alfalfa. This hardiness may be due to a strain of the yellow-flowered alfalfa (*Medicago falcata*). There is the sand lucern and variegated alfalfa and varieties designated by the names of the countries of their derivation, as the American, Arabian, German, Peruvian and Turkestan varieties. The Turkestan variety is well-adapted to drought resistance. Arabian alfalfa is suited to warm conditions, as in Arizona and Texas, while Peruvian alfalfa is adapted to countries where irrigation is practiced.

Soil and Planting.—The soil should be in excellent tilth at planting time with a fine top for the seeding bed. The soil should be neutral and well drained with an open sub-soil permitting the penetration of the alfalfa roots. The seeds should be carefully selected with perfect vitality and clear of weed seeds. Southern-grown seeds should not be used in the north as there is a danger of winter-killing. The time of sowing alfalfa varies in the different sections of the country, but late summer seeding is usually best in the east and south. Spring seeding is the rule in the irrigated and semi-arid sections of the west. The seeds should be covered and not sown on the surface of the ground. Alfalfa may be planted with a drill, or seeded broad-cast with a hand seeder, or wheel-barrow seeder. It is usually best to sow half the seed one way across the field and the other half at right angles to the line of the first sowing. The quantity of seed required per acre is greater in the humid sections than in the semi-arid and irrigated regions. Twenty pounds of seed per acre is usually recommended, although in the west fair stands have been secured with one to five pounds. A pound of ordinary alfalfa contains 220,000 seeds.

Treatment.—If seeded in the late summer or early autumn, alfalfa will require no treatment that fall unless it grows a foot long before winter arrives. Then it should be clipped back to about eight, or ten inches. The first cutting of hay should be secured in the late spring. Ordinarily, no treatment is required during the second season, except to cut the plants when they are about one-tenth in bloom. No pasturing should be allowed during the first and second seasons. As alfalfa lasts about twelve years, the subsequent care of the crop should be governed by the appearance of weeds and bare spots. A disk harrow may be used advantageously in loosening up the soil and destroying weeds.

Harvesting.—The methods of harvesting hay vary considerably. The ideal should be to get the alfalfa into the loft with the least possible handling and exposure to the weather, as its leaflets readily drop off. This results in a serious loss, as three-fifths of all the protein in the plant is contained in the leaves. The hay may be stacked, or baled, or converted into ensilage. Alfalfa is an ideal soiling crop. Grazing of the plant should be done sparingly.

Use as a Feed.—Alfalfa can be used in the feeding of dairy cows, as roughage for beef cattle. Alfalfa is an ideal hay for sheep, but it is apt to cause bloat, if the sheep are turned into alfalfa pastures. Hogs may be fed cut alfalfa in the green state, or in pasture and horses too may be given green alfalfa and hay made from the plant. Alfalfa is an excellent feed for poultry and its nectar is converted by bees into excellent honey. It is one of the most highly nutritious and palatable of feeds either in the green state, or as hay. Fresh alfalfa contains 71.8 per cent. of water: 2.7 per cent. of ash; 4.8 per cent. protein; 7.4 per cent. of crude fiber; 12.3 per cent. of nitrogen free extract and 1.0 per cent. of the extract fat. Alfalfa hay contains 8.4 per cent. of water; 7.5 per cent. of ash; 14.3 per cent. of protein; 25.0 per cent. of crude fiber; 42.7 per cent. of nitrogen free extract and 2.2 per cent. of the extract (fat). The value of alfalfa hay is slightly more than double that of timothy. Alfalfa hay is richer than red clover

FIG. 79.

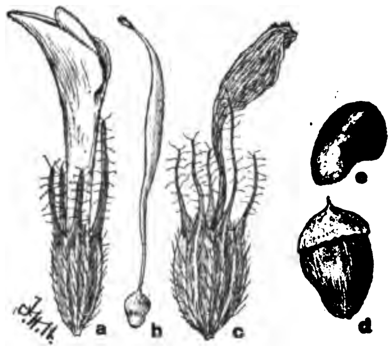


FIG. 80.

FIG. 79.—Red clover (*Trifolium pratense*). (*After Piper, C. V.: Leguminous Crops for Green Manuring. Farmers' Bulletin* 278, 1907, *p.* 15.)

FIG. 80.—Stages in the development of red clover seed: *a* and *c*, Flower in prime and ripe; *b* and *d*, immature and mature seed vessel; *e*, mature seed. (*After Westgate, J. M. and Hillman, F. H.: Red Clover. Farmers' Bulletin* 455, 1915, *p.* 9.)

hay in digestible crude protein, but is lower in fat and contains slightly less digestible carbohydrates. Respiration experiments show that clover hay furnishes slightly more net nutrients than alfalfa hay.

Red Clover (*Trifolium pratense*).—Red Top is a biennial, or a perennial plant of short duration with spreading stems eighteen inches to two feet tall and pubescent from a tap root, which reaches a depth of three to six feet. The stipules are large at the base of a petiole, which is two to three inches long, bearing three ovate to elliptic leaflets with an entire margin. The floral heads are large, globose to hemispherical with pink papilionaceous flowers (Fig. 79). The calyx is five-toothed, with narrow, hairy teeth. The pod is one- to two-seeded (Fig. 80). This clover was introduced from Europe and is now growing spontaneously throughout North America. Linnæus in his original description of the plant in "Species Plantarum," 1753, says "Habitat in Europæ graminosis." Protandry is the rule with red clover flowers and they must be cross-pollinated in order to set seed. The story, that red clover grown in New Zealand failed to set seed until the bumble bee was introduced into the country, has been contradicted, but this can be said that the bumble bee is the most efficient of all the insect pollinating agents, while the honey bee with a proboscis 6 mm. in length is 3.6 mm. shorter than the average of the corolla tubes of the first crop, red clover flowers. In 1911, the honey bee proved to be an efficient cross pollinator.

Treatment.—Red clover is the staple, leguminous forage crop in the north central and northeastern states. Any soil that will grow satisfactory crops of corn will produce good returns from red clover. A deep soil is desirable as the roots extend some distance into it. The presence of humus is requisite as the plant does not grow well in its absence. Red clover is usually sowed in the spring on winter grain, and at that time no special preparation of the seed bed is necessary, as the first has pulverized the soil. Clover seed should be sown with one of the various kinds of grass seed drills on the market at the rate of eight to ten pounds of seed to the acre planted one to two inches deep. This weight of seed is often mixed with ten to twelve pounds of timothy. When seeded with a grain nurse crop, no special treatment is given clover the first season. It develops in the stubble after the grain has been cut and occasionally may afford some pasture the same fall. Cutting should be deferred until the second year, when a cut can be made for hay and a second crop for seed. When mixed with timothy, the stand is often allowed to remain three or four years with a gradual decrease in the clover plants. When seeded in the fall in corn or with rape, one or two crops may be expected the following season in addition to considerable pasture. A top-dressing of barn-yard manure at any time acts beneficially on red clover.

Harvesting and Yield.—Red clover is best harvested for hay when one-third of the blossoms have begun to turn brown. At this time the plant contains the maximum of nutrients. When cut as a soiling crop, the cutting may begin, as soon, as the first flowers appear, and if used for silage, the plants should be fully mature. Some farmers prefer to pasture their clover instead of cutting it. Sometimes the crop is grown for seed which may be successfully produced in regions where clover hay is produced. Each head produces an average of twenty-five to thirty seeds each, which would make the yield one to two bushels to the acre. The self-rake reaper is the best machine to harvest the crop for seed, while a clover huller is used in the threshing operations. The average yield of clover hay per acre, according to the census of 1910, was 1.29 tons, but under favorable conditions the yield in two cuttings ranged from two to four tons to the acre.

Nutrient Value.—Red Clover is one of the most highly nutritious forage plants either in the green state, or cured as hay. Clover hay contains 15.3 per cent. water, 6.2 per cent. ash, 12.3 per cent. protein, 24.8 per cent. crude protein, 38.1 per cent. introgen free extract, 3.3 per cent. ether extract (fat), of these constituents 67 per cent. protein 53 per cent. crude fiber 78 per cent. nitrogen-free extract and 65 per cent. ether extract (fat) are digestible. Many rotations in which red clover enters have played a prominent part in the agriculture of America. A common rotation is corn followed by oats, which in turn are followed by wheat. The wheat in turn acts as a nurse crop for the red clover sown with it. After clover has stood two years, the clover soil is plowed down to corn again. There are rotations of clover with rye or cotton, etc.

Varieties.—The recognized varieties of red clover are the ordinary red clover, the mammoth red clover, the Russian red clovers and special forms of red clover, which have been bred for their disease-resistant qualities.

Alsike Clover (*Trifolium hybridum*).—This is a clover intermediate in appearance between red and white clover and was supposed by Linnæus to be a natural hybrid of the two other clovers. Alsike clover is adapted remarkably to wet soils and also to soils which are too low in humus to grow red clover to advantage. Seed may be obtained from the first crop although an early clipping, especially if there is a wet spring, will result in a better crop of seed. Excellent honey is obtained from the flower. The alsike clover plant is a perennial plant lasting from three to five years and longer. It is an erect, branching, rather stout, smooth herb growing one to three feet tall arising from a large tap root. The leaves are long with greenish veins and taper-pointed stipules. They have a slightly bitter taste. The flowers are pedicelled and white to pink. The pods are two- to four-seeded. The seeds lose their vitality rapidly after the second year. The seed is smaller than red clover and is seeded at the rate of four to eight pounds per acre. The plant is hardier than red clover and matures about two weeks earlier, and therefore, should be grown with early maturing grasses, such as, orchard grass and red top.

FIG. 81.—Crimson clover (*Trifolium incarnatum*). (*After Ball, Carleton R.: Winter Forage Crops for the South. Farmers' Bulletin* 147, 1902, *p.* 30).

Crimson Clover (*Trifolium incarnatum*).—The French clover is an erect, pubescent annual growing from six inches to two feet tall. Its leaves have long petioles with purple-margined, broad stipules (Fig. 81). The bright crimson flowers are produced in a spike, which is two or three inches long. The seed is shiny, when fresh, and of a pink color. This clover is a native of Mediterranean Europe and has been cultivated in this country since 1822.

Treatment.—It is adapted especially for use as a cover crop, and as a green manure in the Atlantic states. It is seeded in August alone, or in corn. The special advantage in its growth lies in the fact that its autumn, winter and early spring development, is sufficient so that it may be turned under the following spring in time for the planting of another crop, such as corn in the north, or cotton in the south. It is also valuable for pasturing, soiling, or for ensilage coming at a time when other green forage is scarce. It should not be fed when the flowers have developed, for as previously narrated, crimson clover hair balls may kill horses and other animals by an obstruction of the bowels. Both the hay and seed crops are handled in about the same way as red clover. It is a hard crop to establish for the absence of rains in late summer is responsible for most of the failures to obtain a satisfactory stand. Crimson clover is benefitted by a liming of the soil. Shallow seeding, using fifteen pounds per acre, has been found to be the best practice. Ordinarily no special treatment is required after seeding and before the winter arrives. Some fall pasturage may be obtained, if the growth be sufficiently rank.

Use.—Crimson-clover hay is considered by dairymen to be fully equal, if not superior, to red, or alsike clover, as a roughage for their cows, sheep, horses, mules and other animals in sections where grown. It is gathered to some extent for the making of bouquets, when in full flower.

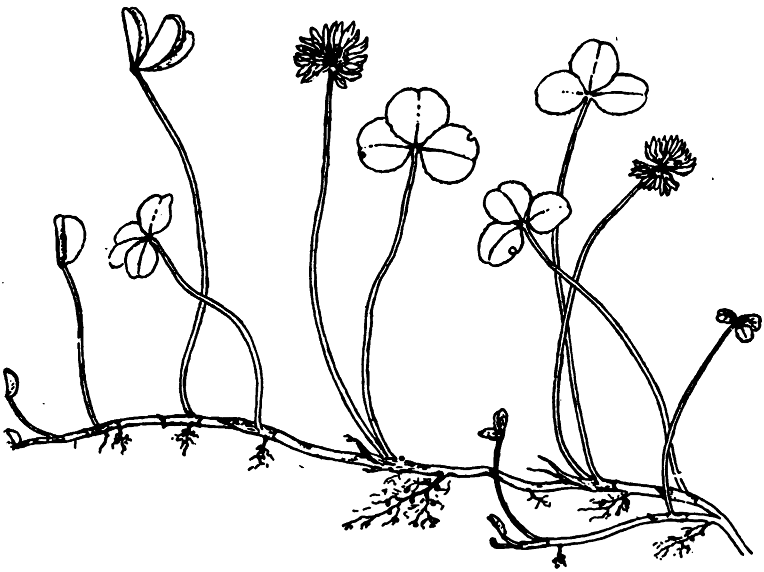


FIG. 82.—White clover, showing creeping habit, one-half natural size. (*After Jones, L. R.: Vermont Grasses and Clovers. Bulletin* 94, *Vermont Agricultural Experiment Station, May,* 1902.)

White Clover (*Trifolium repens*).—This clover, growing wild everywhere in America, was introduced from Europe. In Ireland, it is known as the shamrock and is raised in pots for distribution by the big department stores on St. Patrick's day. The plant is perennial growing by means of prostrate stems rooting at the nodes (Fig. 82). The leaves are trifoliate, obcordate with narrow membranous stipules. The inflorescence is a head of white, or pinkish flowers, which are fragrant and yield a honey of the first quality. The mature flowers, which turn brown in color, are reflexed on the peduncle of the head. Cross pollination by insects is necessary for the production of seeds. The small pods are usually four seeded.

Utility.—The plant is adapted only for pasturage, as it does not attain sufficient height to be mown for hay. Some attribute the fine flavor of the mutton from the Southdown breed of sheep in England, as due to the animals feeding on the white clover pasturage of the chalk downs of the south-eastern part of that country. However, that may be, white clover is a plant which can withstand the close cropping to which turf is subjected by flocks of sheep feeding in the open. White clover is frequently used in lawn mixtures, but on golf courses, it is not usually welcomed. The good points of white clover as a turf plant are its ability to grow on poor soil, to form a close, dense mat, and to withstand very close clipping. On putting greens, white clover is looked upon as a weed.

Fig. 83.—Sweet clover (*Melilotus alba*). (Division of Bot., U. S. Dept. of Agriculture). (*Reproduced in Pammel, L. H.: Some Weeds of Iowa. Bull.* 70, *Experiment Station, Iowa State College,* 1903, *p.* 352.)

Rotation.—The seed crop matures in July and August in the northern states and the yield of seed varies from two to six bushels per acre. A two-year rotation of barley one year followed by white clover for seed the second is common in eastern-central Wisconsin. Elsewhere, it is seeded with bluegrass, and rarely, if ever, causes bloat as red clover is apt to do. The giant white, or Ladino clover (*Trifolium repens var. lata*) is a tall-growing variety of white clover originally from Italy affords good pasturage.

Sweet Clover (*Melilotus alba*).—The ordinary, white sweet clover is a biennial plant developing from a heavy tap-root with lateral branches and with small white tubercles on the smaller rootlets and near the crown of the root. During the first year, it is an erect, stemmy plant with somewhat scattered leaves. These leaves are petioled and pinnately trifoliate and at their bases are large stipules. The flowers are small borne in long, slender racemes (Fig. 83). The calyx teeth are short and subequal. The standard is obovate, or oblong, the wings oblong and the keel short and obtuse. Ten diadelphous stamens occur and the ovary is superior with a thread-like style. The pods are globose, small and one-seeded. The first season it makes a growth of eighteen to thirty inches in height and stores in the tap-root a considerable amount of reserve food. During the second season, it makes a growth of five to twelve feet and dies when the seeds are mature.

Distribution and Soils.—The sweet clover, also known as Bokhara clover, is a native of central Asia introduced about two thousand years ago into the Mediterranean region, where it has been utilized as a honey plant and for forage purposes. It was introduced into America as early as 1738, but its value was not recognized until about twenty years ago. It is at present grown extensively as a field crop in Alabama, Mississippi, Kentucky and Utah and locally on a field scale in Nebraska, Colorado, Wyoming, Iowa, Wisconsin, Illinois, Indiana and Ohio. About Philadelphia, it is thoroughly naturalized. It is an indicator of good alfalfa soils, for where sweet clover grows, alfalfa will grow, and as it is spread over all parts of the United States, this test is of general applicability through the length and breadth of our land. Almost any reasonable well-drained soil will grow sweet clover. It is more tolerant of poor draining than either alfalfa, or red clover. It makes its best growth on rich, well-limed soils.

Seeding.—The seed bed should be well compacted with enough loose soil on top to cover the seeds which are sown at the rate of twenty to thirty pounds of hulled seeds and at least five pounds more of unhulled seed per acre. Early spring seeding has been found satisfactory in many sections. When sown in ordinary cultivated fields, sweet clover is usually sown later in the spring and with a nurse crop of spring-sown grain. Fall seeding is successful in regions with mild winters. Where seeded in the spring without a nurse crop, no special treatment is required the first season unless it is necessary to check the weeds. When seeded with a nurse crop, such a crop may be cut for grain, if the moisture conditions are favorable, but if a drought threatens the sweet-clover, the crop should be cut for hay. A good hay crop, or summer pasture, may be obtained in the south in the first season even when sown with a nurse crop, but in the north a small amount of late pasture only is usually available.

Pasturage and Hay.—Sweet clover produces good pasturage very early in the spring before other pasture plants commence growth. It will furnish a good hay crop in the north in the latter part of June and a second crop of hay, or seed late in the summer. Two crops of hay and one of seed may be obtained in the south during the second season. Sweet clover plants are raked into windrows just before the leaves become dry

FIG. 84.—Canada pea (*Pisum sativum*). (*After Mairs, T. J.: Some Soiling Crops for Pennsylvania. Bull.* 109, *Pennsylvania State College Agricultural Experiment Station*, 1911, *p.* 5.)

enough to shake off the stems. After a day in the windrows, it is shocked and cured.

Nutritive Valve.—Sweet clover may be used as a soiling plant, or as a pasture plant and is a useful soil renovator. It is palatable and nutritious, although it has a bitter taste due to its cumarin content. Fresh sweet clover has the following composition: water 77.0 per cent., ash 1.8 per cent., protein 3.9 per cent., crude fiber 6.9 per cent., nitrogen-free extract 9.4 per cent. and ether extract (fat) 0.6 per cent. Sweet clover hay contains water 7.7 per cent., ash 7.5 per cent., protein 13.3 per cent., crude fiber 26.9 per cent., nitrogen-free extract 42.6 per cent. and ether extract 2.1 per cent. It has been determined that the value of sweet-clover hay is almost double that of timothy and intermediate between red clover and alfalfa.

Field Pea (*Pisum sativum* var. *arvense*).—The field pea also called the Canadian field pea (Fig. 84) differs slightly from the garden pea (*P. sativum*) (Fig. 85). They have violet flowers and small gray, or buff seeds, which are rather angular, but not wrinkled, while garden peas have white flowers and whiter, more globular seeds, which may be either smooth, or wrinkled. The field pea has hollow, sparingly branched stems, two to five feet long with leaves bearing two, or three pairs of leaflets, one, or two inches long and ending in one or more pairs of tendrils and a long median tendril. There are present leafy stipules. Two, or more flowers are borne in the axils of the leaves on flower stalks shorter than the leaves. The legume is finally flat, many-seeded and from two to four inches long. The seeds are smooth, hard and rather, angular and gray-green, gray-yellowish, or gray dotted with purple, blue, rust-red, or brownish spots.

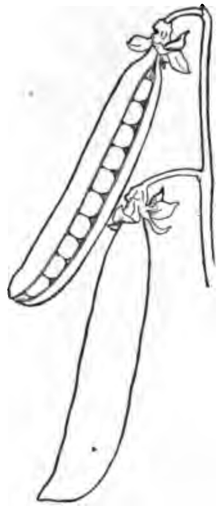


FIG. 85.—Pods of garden pea (*Pisum sativum*). (*After Abel, Mary H.: Beans, Peas and other Legumes as Food. Farmers' Bulletin 121, 1900, p. 13.*)

Cultivation and Harvesting.—The plant is adapted to growth in climates with a cool growing season, as in Canada, Michigan and Wisconsin. The yield in Canada is from thirty-five to forty bushels and in the above states sixteen bushels per acre. Any soil, that will raise oats, will raise field peas. Sandy soils are better than clay soils. The pea has a high germinating power and will start at quite a low temperature. The seeds should be sown, as early, as possible in the spring, and hence, sandy soils permit the adoption of this principle of sowing. Peas should be sown deeply and broadcast. A disk harrow should be used to cover the seeds, which should be used at the rate of 1.5 to 3.5 bushels per acre. Harvesting is difficult, because of the prostrate habit of the plants. They may be cut with the ordinary mowing machine and raked into piles with a sulky rake. It is customary to harvest when two-thirds of the pods are yellow. When dried, the hay should be stacked under cover, or threshed at once with a pea huller.

FIG. 86.—Cowpea (*Vigna sinensis*) with pods and leaves. (*After Mairs, T. J.: Some Soiling Crops for Pennyslvania, Bull.* 109, *Pennsylvania State College Agricultural Experiment Station*, 1911, *p.* 7. *Oirginally on p.* 17, *U. S. Farmers' Bulletin* 278, 1907.)

Utility.—Peas furnish a good food for milk cows, swine, sheep, horses and cattle. Peas grown with some other kinds of grain are of great value as a soiling crop. Peas can be used as nitrogen gatherers, and therefore, for green manure. Field peas are treated as a hay crop, for the making of silage and is a cover crop. The Ontario Station after testing for six years found a yield of 28.1 bushels per acre from large seed and 23 bushels from small seed.

Cowpea (*Vigna sinensis*).—This plant is related to the asparagus bean (*Vigna sesquipedalis*) and to the catjang (*Vigna catjang*). The differences botanically by which these species are distinguished are comparatively slight, and the species are connected through intermediate varieties. The cowpea (*Vigna sinensis*) is an annual, prostrate, trailing to half-bushy plant having compound trifoliate leaves with broadly ovate leaflets.

The flowers are white, or pale violet with three bractlets at the base of each pedicel, and they are close pollinated, although the flowers are visited by honey bees and bumble-bees attracted by the extrafloral nectaries. The pods are long, cylindrical, curved and usually constricted between the many seeds, which are bean-shaped, spotted, marbled and speckled with a dark circle around the white hilum. Some of the varieties of the cowpea are Whippoorwill, Wonderful, New Era, Groit, Iron, Clay, Black, Taylor and Red Ripper (Fig. 86).

Utility.—The cowpea is the most common legume planted in the entire cotton belt and it can be profitably grown much farther north. It is especially suitable for combined hay and seed production, or for hay alone, and it is utilized for pasture and as a green manure for soil improvement. Cowpeas for hay production are grown advantageously in mixture with sorghum, Johnson grass, or soy-beans. The yield is thus increased, the quality improved, and the curing more easily done. To make good cowpea hay requires a careful handling of the crop. The use of a tedder is helpful, and the curing is best done in small cocks, and the hay is ready for the stack, or barn, when no moisture can be wrung from the stem by twisting it with considerable force. Cowpea hay is very nutritious being nearly equal to wheat bran as a part of a ration.

Rotations.—The following rotations have been used in the south with good results: cotton three years; corn and cowpeas fourth year and then cotton again. This is satisfactory for the better soils, but for the poorer soils cotton should be planted for only two years. Wheat, or oats, can be grown with cowpeas each season after removal of the grain crop. The land is seeded to grain again in the fall, making two crops a year from the same land. Cotton, first year; corn and cowpeas, second year; winter oats, or wheat followed by cowpeas as a catch crop, third year; and then cotton again. The seeds are fed to poultry and are also used as a food for man. The roasted seeds form a substitute for coffee.

Soy (*Glycine hispida*) is a native of Asia, where it has been grown since ancient times in Japan, Korea, Manchuria and China, especially in Shansi and Shantung and in India. The chief varieties grown in the United States are Ito San, Mammoth, Buckshot, Guelph, Eda, Butterball, Kingston, Ogemaw, Samarow and many others which have lately been grown.

Description.—All soy-beans are strictly determinate as to growth, reaching a definite size, then mature and die. The plants are erect and branching from a short, strong tap root. The leaves are trifoliate with ovate to lanceolate leaflets to nearly orbicular (Fig. 87). All soy plants are hairy with two colors of pubescence, white, or gray and tawny. The flowers are purple and white borne in short axillary racemes with eight to sixteen flowers in each cluster. The pods are compressed, borne in clusters

FIG. 87.—Soy bean (*Glycine hispida*) with hairy fruit. (*After Abel, Mary H.: Beans, Peas and other Legumes as Food. Farmers' Bulletin* 121, 1900, *p.* 19.)

of three to five, and are gray or tawny. Gray pods bear white, or grayish, hairs and tawny pods have tawny pubescence. Two or three seeds occur in each pod, which are readily discharged. The seeds are uniform in color, which run through a gamut, as follows: straw-yellow, olive-yellow, olive-green, brown and black. The hilum is pale in some varieties and dark in others.

Cultivation.—Soy-beans will withstand considerable frost, and they will succeed on nearly all types of soil, but the best crops are obtained in a mellow, sandy loam, or clay loam. They make a satisfactory growth on poor soils. The preparation of the soil for the soy-bean is similar to that for corn. The land should be plowed early and deep, and then harrowed at intervals until the beans are planted. Under nearly all conditions, the soy-bean should be planted in rows and cultivated sufficiently to keep down the weeds. The yield of seed is always greater, when the soy plant is grown in rows.

If the conditions are favorable, the soy-bean germinates in a few days and cultivation should begin, as soon, as the young plantlet appears. One deep cultivation should be given, and after that the cultivations should be shallow. The soy-bean may be used advantageously in many systems of crop rotations. North of the Ohio River, a rotation of corn, soy-beans, wheat and clover is practised. A soy-bean crop is often grown in North Carolina and Tennessee between two wheat crops, or between two oat crops. It can also be used as a catch crop. Soy-beans are more generally grown with corn than with any other crop. The beans may be planted in the same hills with corn in alternate hills with corn in the same row, in alternate rows of each, or there may be two rows of each. When grown with corn, the crop is generally pastured, or made into ensilage. It is a profitable crop when grown for seed, the average yield being about fifteen bushels in the northern states to twenty-five bushels in the southern part of the cotton belt.

As the protein content of soy-bean seeds is thirty to forty-six per cent. their feeding value is high and can be fed whole to sheep and hogs, or used ground for stock feeding and milk production. The total per cent. of digestible nutrients of soy-bean seed is 85.9, of this there is 30.7 per cent. of protein 22.8 per cent. of carbohydrates and 14.4 per cent. of fat.

Harvesting.—The soy plant, when cut at the right stage of growth, makes an excellent hay of high feeding value and this can be used as a home-grown crop to replace the high-priced concentrated feeds which the farmer finds it necessary to purchase. The plant may be cut for hay any time from the setting of the seed until the leaves begin to turn yellow. The plants after being cut should remain in the swath until they begin to wither and should then be raked into windrows before the leaves become dry and brittle and left for a day, or two, when they should be placed in small shocks, or bundles. Later, it should be stacked, or housed.

Nutritive Value.—The feeding value of soy-bean hay lies in its high content of digestible protein. In feeding value, it is superior to cowpeas, or red clover, and is equal to alfalfa for milk and butter production. The percentage of air dry digestible nutrients is as follows: Total 53.6 per cent.; protein 11.7 per cent; 39.2 per cent. of carbohydrates and 1.2 per cent. of fat. The yield of soy-bean hay is from one to three tons to the

FIG. 88.—Peanut (*Arachis hypogaea*) with subterranean pods. (*After Abel, Mary H.: Beans, Peas and other Legumes as Food. Farmers' Bulletin* 121, 1900, *p.* 16.)

acre. Soy-beans can be used for ensilage, for pasture and for soiling purposes.

Human Food.—The soy-bean is one of the most important human foods in China and Japan where it is used by the coolie class in place of meat to overcome a too exclusive diet of rice. The dried beans are used in the manufacture of soy sauce, vegetable milk from which can be obtained cheese, confections and casein. The oil extracted from the seeds may be used in the production of glycerin, enamels, varnish, paints, linoleums, soap stock, as a substitute for butter, lard and salad oils. The green beans can be canned, or used as a green vegetable.

Peanut (*Arachis hypogaea*).—The ground nut, or goober, is an annual semi-erect, or trailing plant with stems one to two feet long, branching and hairy. The leaves are pinnately compound usually with two pairs of subsessile entire leaflets and no tendrils. The stipules are linear-lanceolate and adherent to the base of the petiole. The flowers are axillary, sessile and orange-yellow in color (Fig. 88). Two forms of flowers occur on the same plant. The larger, more terminal ones are usually sterile, while the axial are more numerous, smaller and usually fertile. The flowers have ten monadelphous stamens. The gynophore, geotropic in reaction, elongates after flowering and fertilization, and carries downward the developing ovary until it is buried in the ground, where it matures into an indehiscent pod with a reticulated surface (Fig. 88). The shell is the pericarp, the thin skin surrounding the seeds is the testa or outer seed coat. The cotyledons are large and full of stored food. If the ovary is not buried underground, it fails to develop. The varieties cultivated in America may be divided into the large-podded, or jumbo peanuts, Virginia Bunch, Virginia Runner, Dixie Giant and the Spanish, African and Tennessee Red, which are small-podded. The main types may again be subdivided into the bush and the running kinds.

Seeding and Cultivation.—A good grade of seed should alone be used in planting peanuts in the spring after the soil has become warm, and therefore, a trifle later than corn. Thirty six inches should be left between the rows. As a rule, one and a half pecks of shelled Virginia peanut should be used to plant an acre, or one and a quarter bushels, if planted inclosed in the shell. On heavy soils, three fourths to one inch and a quarter will be sufficient depth to plant the seeds, while on light, sandy soils one inch and a half to two inches may not be too deep. Cultivation of the peanut crop should begin immediately after planting and continue until the vines occupy the ground. Frequent shallow cultivation will keep the soil loose and prevent the loss of moisture. After the peanuts begin to "peg," or form pods, they should not be disturbed, or given cultivation. Most implements used in cultivating corn, or cotton will be found suitable for the peanut crop. The crop should be dug before the first frost, as if deferred too long, the first-formed pods are likely to burst their shells and start growing. Usually the peanuts are plowed from the ground with a one-horse turning plow and afterward separated from the soil by hand. After the peanut vines are loosened from the soil, they are allowed to remain on the ground for three, or four hours, when they are put in small stacks around a central stake to cure. After the peanuts have cured in the stacks from four to six weeks, those intended for feeding stock may be placed in barns. Peanuts for market should be cured in the stack at least three, or four weeks before picking. They should not be picked from the vines until the pods have become dry and the peanuts firm and nutty, when they are picked by hand. Machines have lately been used for picking. After picking, the peanuts should be kept dry and never exposed to wet conditions, as the shells invariably become discolored. The nuts are prepared for market by the removal of all dirt and the separation of nuts into their respective grades.

Nutritive Value.—The peanut is a valuable human food and is sold in large quantities either roasted in the shell at so much per pound, or bag, or shelled and salted in the penny slot machine. Peanut candies and brittle also consume considerable quantities of the hulled seeds, and the manufacture of peanut butter and peanut meal an additional amount. Americans are only beginning to learn what may be done with this valuable plant, as a source of human food. There has arisen during recent years a demand for peanut oil for edible purposes, either as a dressing for salads or in the manufacture of oleomargarine, or in the packing of sardines Low grade oils are used in the manufacture of soap. Peanut hay contains 11.75 per cent. of protein, 46.95 per cent. of carbohydrates and 1.84 per cent. of fat. The peanut is a valuable feed for use in preparing hogs for market. Peanut vines are used for feeding stock and yield a very desirable class of forage.

MISCELLANEOUS LEGUMINOUS FORAGE PLANTS

The activity of the United States Department of Agriculture especially the Bureau of Foreign Seed and Plant Introduction has resulted in the introduction, trial and establishment of a number of additional plants of the leguminous family. A detailed account of these would enlarge unduly the size of this book, and hence only a brief reference to these plants will be made. Of the beans belonging to the genus *Phaseolus*, we have the kidney, or haricot bean (*Phaseolus vulgaris*) a native American plant, whose use was learned from the Indians. Large quantities of this bean are consumed as human food. The Lima bean is *P. lunatus*. It is likewise consumed as a human food. The scarlet runner bean (*Phaseolus multiflorus*) is a strong-growing climbing plant used for decorative purposes on account of its cluster of bright colored blossoms. The tepiary (*Phaseolus acutifolius*) is a newly recognized bean domesticated by the prehistoric tribes of the southwestern United States and Mexico. Among the food plants of secondary importance in different parts of Asia are five annual species of beans that at various times have been introduced into the United States, but concerning which very little definite information

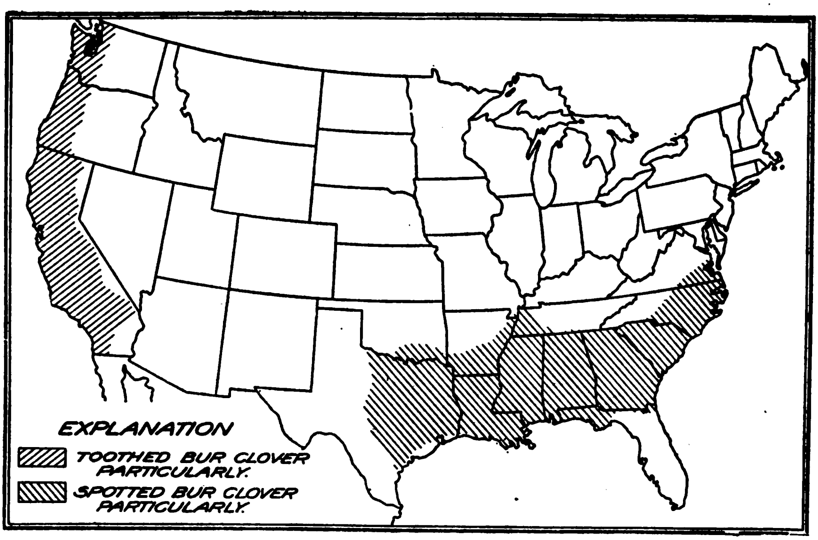


FIG. 89.—Outline map of the United States, showing the regions to which toothed bur clover (*Medicago denticulata*) and spotted bur clover (*Medicago arabica*) are adopted. (*Piper, C. V. and McKee, R.: Bur Clover. Farmers' Bulletin* 693, 1915, *p.* 5.)

has been published. These five are the adsuki bean (*Phaseolus angularis*), the rice bean (*Phaseolus calcaratus*), the mung bean (*Phaseolus aureus*), the urd (*Phaseolus mungo*) and the moth bean (*Phaseolus aconitifolius*). The sprouted mung beans are used as one of the chief constituents of ordinary chop suey, served in Chinese restaurants in the United States.

There are two kinds of bur clover cultivated in the United States, (Fig 89), namely, the spotted, or southern bur clover (*Medicago arabica*) and the toothed, or California bur clover (*Medicago hispidula denticulata*) (Fig. 90). These are used as cover crops, for soil renovation, for pasture and hay. The horse, broad, or Windsor bean (*Vicia faba*) is one of the oldest cultivated plants in Europe, and elsewhere, but of minor importance in the United States, used as human food, and as a valuable stock feed (Figs. 91 and 92). The Japan clover (*Lespedeza striata*) was introduced from China,

FIG. 90.—Bur clover with prickly pods (*Medicago denticulata*). (*After Ball, Carleton, R.: Winter Forage Crops for the South. Farmers' Bulletin* 147, 1902, *p.* 28; *upper figures of pods from Piper, C. V. and McKee, R.: Bur Clover. Farmers' Bulletin* 693, 1915, *p.* 4.)

or Japan into the South Atlantic states, where it is grown for hay and pasture. Sainfoin (*Onobrychis viciæfolia*) was introduced from Asia, but is little grown here. The serradella (*Ornithopus sativus*) is successful on thin soils and makes good hay. The velvet bean (*Mucuna utilis*) is one of the most exacting members of the leguminous family as regards tem-

FIG. 91.—Broad, or Windsor bean (*Vicia faba*). (*After Abel, Mary H.: Beans, Peas and other Legumes as Food. Farmers' Bulletin* 121, 1900, *p*. 6.)

perature, and hence, its growth is confined to Florida and the Gulf coast, where it is used as a green manure and as a forage crop (Fig. 93). Many of the species of vetch have been more or less extensively cultivated, and several others growing wild are used for hay, or pasturage, or in a few cases the seeds are used as human foods. The cultivated kinds include

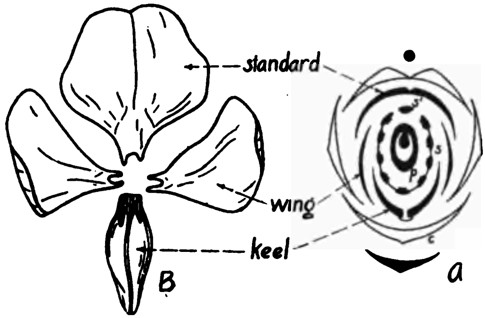


FIG. 92.—Flower of Leguminosæ. *A*, floral diagram of Vicia faba; *B*, sweet pea flower, dissected, diagrammatic. (*A*, *Robbins after Eichler*, *B after Bergen and Caldwell.*)

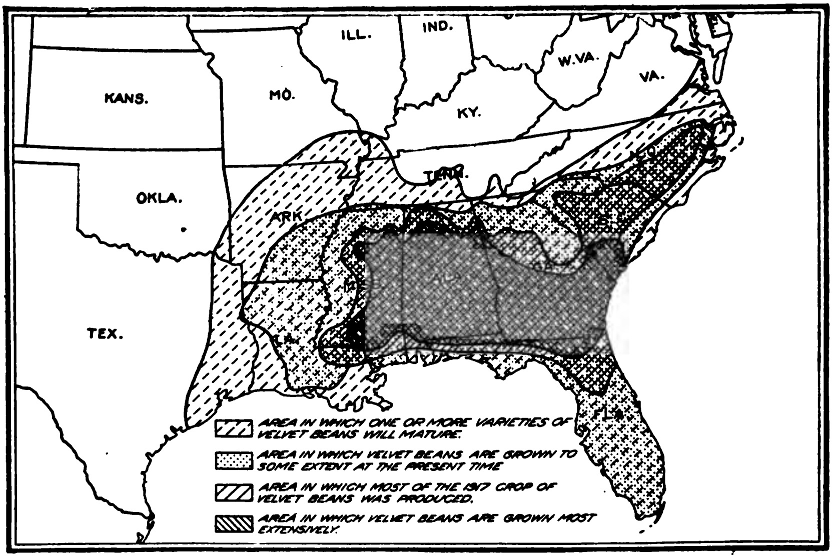


FIG. 93.—Map of the southeastern United States, showing the distribution of velvet beans. (*After Tracy, S. M. and Coe, H. S.: Farmers' Bulletin*, 962, 1918, *p.* 13.)

the following: common vetch, or tares (*Vicia sativa*), hairy, sand, or Russian vetch (*Vicia villosa*), (Fig. 94), bitter vetch (*Vicia ervilia*), scarlet vetch (*Vicia fulgens*), purple vetch (*Vicia atropurpurea*), Narbonne vetch

(*Vicia narbonnensis*), narrow-leaved vetch (*Vicia angustifolia*). Hairy vetch (*Vicia villosa*) is adapted to nearly as wide a range of uses as red clover, and in regions where red clover for any reason does not succeed, it is the best substitute. It makes excellent hay, though it is rather difficult to mow. It furnishes pasturage of high quality and may be grazed in the

FIG. 94.—Hairy vetch (*Vicia villosa*). (*After Mairs, T. I.: Some Soiling Crops for Pennslyvania, Bull.* 109, *Pennsylvania State College Agricultural Experiment Station,* 1911; *p.* 11.)

spring without reducing the hay crop. As a winter cover crop, it gives satisfaction, if sown early, but it makes a slower growth in cold weather than common vetch. It has been found to be the best winter green manure and cover crop for tobacco fields in the Connecticut Valley. The chick-pea (*Cicer arietinum*) is grown in Europe, Asia and Mexico for its seeds, which are used for both stock and human food. The herbage is unfit for stock because of a poisonous principle. The fenugreek (*Trigonella fœnum-grœcum*) is grown principally for its seeds, which have medicinal properties and the plants are used as a green manure for orchards.

Additional Leguminous Forage Plants.—In addition to the above the following leguminous forage plants are noteworthy: shaftal (*Trifolium suaveoleus*) berseem (*Trifolium alexandrinum*), yellow trefoil (*Medicago lupulina*), Dakota vetch (*Hosackia americana*), chickling vetch (*Lathyrus sativus*), bird vetch (*Vicia cracca*), square pod pea (*Lathyrus tetragonolobus*), Florida beggar-weed (*Desmodium tortuosum*), bonavist, or hyacinth bean (*Dolichos lablab*), guar (*Cyamopsis tetragonoloba*), kudzu (*Pueraria thunbergiana*); kidney vetch (*Anthyllis vulneraria*), sulla (*Hedysarum coronarium*), goat's rue (*Galega officinalis*), bird's foot trefoil (*Lotus corniculatus*), furze (*Ulex europæus*).

Miscellaneous Forage Plants

There is a considerable number of forage plants other than the grasses and leguminous species used as food for cattle. They are used incidentally, as occasional, or additional forage plants, or as emergency feeds in the absence, or scarcity, of the leguminous and graminaceous species, which alone are worth cultivating. Some of these miscellaneous herbs used as forage are here enumerated.

Prickly Pear (*Opuntia* spp.).—A variety of the fleshy, spiny cacti all natives of the arid regions of the west are used as forage. The practice has been to burn off the spines, as they are injurious and to feed the fleshy joints to stock. Recently an attempt has been made by Burbank and other plant breeders to select and propagate in field culture a spineless cactus, so as to overcome the objectionable spines in the unselected kinds. Prickly pears are readily eaten by cattle, hogs, sheep and goats.

Australian Saltbush (*Atriplex semibaccata*).—This plant from the alkali lands of Australia has been introduced into the United States as a forage for sheep.

It has become naturalized in California, but in general, it has proved disappointing in this country.

Sachalin (*Polygonum sachalinense*).—This tall, rapidly growing plant was introduced from the Island of Saghalin about 1893, as a forage plant. It produces an abundance of herbage, readily eaten by cattle, but its rapid, weedy growth, woody stems and persistence in cultivated fields renders it objectionable as a forage plant.

Spurrey (*Spergula sativa*).—This plant was cultivated as early as 1566 in Europe as a forage plant. It has been used as a catch crop and on the sandy soils of Europe, its growth is rapid. It is looked upon in Europe as a valuable crop, but has not been used generally in America.

Mexican Clover (*Richardsonia scabra*).—This rubiaceous annual is native to Mexico coming up in cultivated land in spring and forming a dense herbage under favorable conditions. It is, when cured, readily eaten by farm animals.

Sunflower (*Helianthus annuus*).—Sunflowers are grown in Kansas and elsewhere in the west for their seeds, which form an important poultry feed and for oil production.

Artichoke (*Helianthus tuberosus*).—The tubers of this sunflower are chopped up and form one of the most useful feeds for hogs during the winter months.

Burnet (*Sanguisorba minor*).—This deep-rooted, European perennial is used as a pasture plant in England and France, but in America, it has not been found sufficiently valuable to justify cultivation.

Rib-grass (*Plantago lanceolata*).—This European weed is common everywhere in America, and is looked upon as a troublesome plant in alfalfa and red clover fields, but its leaves are readily eaten by sheep and cattle, when cured into hay. It may prove useful as a pasture plant for thin, stony soils.

Prickly Comfrey (*Symphytum asperrimum*).—This perennial herb came from the Caucasus region. It has been raised in England as a green forage for cows, hogs and sheep, but has not been used much in America.

Emergency Feeds.—In the scarcity of the usual forage plants on the western and stock ranges, it has been the practice to feed native desert species in the chopped-up condition to stock. The following plants have been found useful in tiding over the period of forage scarcity: soap weed (*Yucca elata*), bear-grass (*Yucca glauca*), sotol (*Dasylirion texanum, D. Wheeleri*), lechuguila (*Agave lechuguila*) and nolina (*Nolina erumpens* and *N. microcarpa*). As feed, they are of low value, but will keep stock from starving.

General Bibliography

A Virginia Farmer. Roman Farm Management. The Treatises of Cato and Varro done into English with Notes of Modern Instances. New York, The MacMillan Company, 1913.

Gardner, Frank D.: Successful Farming. Philadelphia, John C. Winston Company, 1916.

Griffiths, David: Prickly Pear as Stock Feed. Farmers' Bulletin 1072, March, 1920.

Hall, A. D.: The Book of Rothamsted Experiments. New York, E. P. Dutton and Company, 1905.

Hall, A. D.: A Pilgrimage of British Farming, 1910–1912. New York, E. P. Dutton and Company, 1913.

Henry, W. A. and Morrison, F. B.: Feeds and Feeding, a Handbook for the Student and Stockman. Madison, Wisconsin, The Henry-Morrison Company, 1915.

Hunt, Thomas F.: The Forage and Fiber Crops in America. New York, Orange, Judd Company, 1912.

King, F. H.: Farmers of Forty Centuries, China, Korea, Japan. Madison, Wisconsin, Mrs. King, 1911.

Piper, Charles V.: Forage Plants and Their Culture. New York, The MacMillan Company, 1914.

Robbins, Wilfred W.: The Botany of Crop Plants. Philadelphia, P. Blakiston's Son & Co., 1917.

Bulletins and Other Publications Arranged by Crops

Alfalfa

Brand, Charles J.: Peruvian Alfalfa: A new Long-season Variety for the Southwest. Bulletin 118, Bureau of Plant Industry, U. S. Department of Agriculture, 1907; Grimm Alfalfa and its Utilization in the Northwest. Bulletin 209, Bureau of Plant Industry, 1911; with L. R. Waldron: Cold Resistance of Alfalfa and some Factors Influencing It. Bulletin 185, Bureau of Plant Industry, 1910.

Brown, Edgar: Alfalfa Seed. Farmers' Bulletin 194, U. S. Department of Agriculture, 1904.

Doyle, H. W.: Alfalfa in Kansas. Report Kansas State Board of Agriculture for the Quarter Ending June, 1916.

Drake, J. A., Rundles, J. C. and Jennings, Ralph D.: Alfalfa on Corn-belt Farms. Farmers' Bulletin 1021, U. S. Department Agriculture, 1919.

Fortier, Samuel: Irrigation of Alfalfa. Farmers' Bulletin 373, U. S. Department of Agriculture, 1909; Farmers' Bulletin 868, 1917.

Hansen, N. E.: The Wild Alfalfas and Clovers of Siberia, with a Perspective View of the Alfalfas of the World. Bulletin 150, Bureau of Plant Industry, 1909.

Hitchcock, A. S.: Alfalfa Growing. Farmers' Bulletin 215, 1905.

McKee, Roland: Nonperennial Medicagos; the Agronomic Value and Botanical Relationship of the Species. Bulletin 267, Bureau of Plant Industry, 1913.

Oakley, R. A., and Westover, H. L.: Commercial Varieties of Alfalfa. Farmers' Bulletin 757, 1916.

Oliver, George W.: Some New Alfalfa Varieties for Pastures. Bulletin 258, Bureau of Plant Industry, 1913.

PIPER, C. V.: Alfalfa Seed Production: Pollination Studies. Bulletin 75, U. S. Department of Agriculture, 1914.

SCOFIELD, CARL S.: The Botanical History and Classification of Alfalfa. Bulletin 131, Part II, Bureau of Plant Industry, 1908.

SMITH, JARED G.; Alfalfa or Lucern. Farmers' Bulletin' 31, 1895.

WESTGATE, J. M.: Alfalfa. Farmers' Bulletin 339, 1908; Variegated Alfalfa. Bulletin 169, Bureau of Plant Industry, 1910.

WESTGATE, J. M., MCKEE, ROLAND and EVANS, M. W.: Alfalfa Seed Production. Farmers' Bulletin 495, 1912.

RED CLOVER

BROWN, EDGAR and HILLMAN, F. H.: Seed of Red Clover and Its Impurities. Farmers' Bulletin 260, 1906.

MCDERMOTT, LAURA FRANCES: An Illustrated Key to the North American Species of Trifolium. San Francisco, Cunningham, Curtiss, Welch, 1910.

SHAW, THOMAS: Clovers and How to Grow Them. New York, Orange Judd Company, 1906.

SMITH, C. BEAMAN: Clover Farming on the Sandy Jack-pine Sands of the North. Farmers' Bulletin 323, 1908.

WESTGATE, J. M. and HILLMAN, F. H.: Red Clover. Farmers' Bulletin 455, 1911.

WESTGATE, J. M. AND OTHERS: Red-clover Seed Production: Pollination Studies. Bulletin 289, U. S. Department of Agriculture, 1915.

CRIMSON CLOVER

WESTGATE, J. M.: Crimson Clover. Growing the Crop. Farmers' Bulletin 550, 1913; Crimson Clover. Utilization. Farmers' Bulletin 579, 1914.

SWEET CLOVER

COE, H. S.: Sweet Clover. Growing the Crop. Farmers' Bulletin 797, 1917; Sweet Clover. Utilization. Farmers' Bulletin 820, 1917; Sweet Clover Harvesting and Thrashing the Seed Crop. Farmers' Bulletin 836, 1917.

DRAKE, J. A. and RUNDLES, J. C.: Sweet Clover on Corn Belt Farms. Farmers' Bulletin 1005, 1919.

WESTGATE, J. M. and VINALL, H. N.: Sweet Clover. Farmers' Bulletin 485, 1912.

FIELD PEAS

SHAW, THOMAS: Canadian Field Peas. Farmers' Bulletin 224, 1905.

VINALL, H. N.: The Field Pea as a Forage Crop. Farmers' Bulletin 690, 1915.

COW PEAS

NIELSEN, H. T.: Cowpeas. Farmers' Bulletin 318, 1908.

PIPER, C. V.: Agricultural Varieties of the Cowpea and immediately Related Species. Bulletin 229, Bureau of Plant Industry, 1912.

SMITH, JARED G.: Cowpeas. Farmers' Bulletin 89, 1899.

Soy-beans

Morse, W. J.: Harvesting Soy-bean Seed. Farmers' Bulletin 886, 1917; The Soy-Bean: its Culture and Uses. Farmers' Bulletin 973, 1918.

Piper, C. V. and Morse, W. J.: The Soy Bean: History, Varieties and Field Studies. Bulletin 197, Bureau of Plant Industry, 1910.

Piper, C. V. and, Nielsen, H. T.: Soy-Beans. Farmers' Bulletin 372, 1909.

Williams, Thomas A.: Soy-Beans as a Forage Crop. Also Longworthy, C. F.: Soy-Beans as Food for Man. Farmers' Bulletin 58, 1897.

Peanuts

Beattie, W. R.: Peanuts. Farmers' Bulletin 356, 1909; The Peanut. Farmers' Bulletin 431, 1911.

Ed. Groundnuts. Gardeners' Chronicle, new ser., xiv, 293, September 4, 1880.

Handy, R. B.: Peanuts: Culture and Uses. Farmers' Bulletin 25, 1895.

Thompson, H. C. and Bailey, H. S.: Peanut Oil. Farmers' Bulletin 751, 1916.

Waldron, Ralph A.: The Peanut, its History, Histology, Physiology and Utility. Contributions Botanical Laboratory, University of Pennsylvania, iv, 301–338, 1919.

Miscellaneous Forage Plants

Abel, Mary Hinman: Beans, Peas and other Legumes as Food. Farmers' Bulletin 121, 1900.

Ball, Carleton R.: Winter-Forage Crops for the South. Farmers' Bulletin 147, 1902.

Cook, O. F.: Olneya Beans. A Native Food Product of the Arizona Desert. Journal of Heredity, x, 321–331, October, 1919.

Corbett, L. C.: Beans. Farmer's Bulletin 289, 1907.

Piper, C. V.: Kudzu, Circular 89, U. S. Department of Agriculture, 1920.

Piper, C. V. and Morse, W. J.: Five Oriental Species of Beans. Bulletin 119, U. S. Department of Agriculture, 1914.

Piper, C. V. and McKee, Roland: Bur Clover. Farmers' Bulletin 693, 1915; Vetches. Farmers' Bulletin 515, 1912.

McKee, Roland: Purple Vetch. Farmers' Bulletin 967, 1918; Horse Beans, Farmers' Bulletin 969, 1918.

McNair, A. D. and Mercier, W. B.: Lespedeza, or Japan Clover. Farmers' Bulletin 441, 1911.

Norton, J. B. S. and Walls, E. P.: The Wild Legumes of Maryland and their Utilization. Bulletin 100, Maryland Agricultural Experiment Station, 97–124, March, 1905.

Smith, A. G.: Vetch Growing in the South Atlantic States. Farmers' Bulletin 529, 1913.

Tracy, S. M. and Coe, H. S.: Velvet Beans. Farmers' Bulletin 962, 1918.

Miscellaneous Non-leguminous Plants

Forsling, C. L.: Chopped Soapweed as Emergency Feed for Cattle on Southwestern Ranges. Bulletin 745, U. S. Department of Agriculture.

GRIFFITHS, DAVID: The Prickly Pear and other Cacti as Food for Stock. Bulletin 74, Bureau of Plant Industry, U. S. Department of Agriculture, 1905; The Prickly Pear as a Farm Crop. Bulletin 124, Bureau of Plant Industry.

KENNEDY, P. BEVERIDGE: Salt Bushes. Farmers' Bulletin 108, U. S. Department of Agriculture, 1900.

LAMSON-SCRIBNER, F.: Southern Forage Plants. Farmers' Bulletin 102, 1899.

MCKEE, ROLAND: Australian Salt Bush. Bulletin 617, U. S. Department of Agriculture, 1919.

PIPER, CHARLES V.: Forage Plants and Their Culture. New York, The MacMillan Company, 1914.

WOOTON, E. O.: Certain Desert Plants as Emergency Stock Feed. Bulletin 728, U. S. Department of Agriculture, 1918.

LABORATORY WORK

Suggestion to Teachers.—The suggestions that have been made for the provision of alcoholic, dried and living material for the prosecution of the laboratory work connected with this chapter holds good. The teacher should provide dried plants of alfalfa, red clover, crimson clover, alsike clover, white clover, sweet clover, cowpeas, soy-beans and peanuts for a detailed study by the class. Fresh peanuts can always be had during the winter months. If the institution is provided with greenhouse facilities some of the clovers can be transplanted to flats in the greenhouses during the summer, while cowpeas, soy-beans and peanuts are easily grown in pots, especially the plants which in the absence of a greenhouse can be grown to the development of mature fruits in a warm sunny window of an ordinarily heated house. Dried specimens of the fruits and seeds of each of these plants and of the rarer kinds should be kept for class demonstration. Charts, maps of distribution, book illustrations, lantern slides and moving picture films of field operations should be collected by the larger and better endowed institutions. There can be no limit to the different plants used in connection with the subject matter of this chapter in any part of the world. The abundant plants of the locality should be utilized.

LABORATORY EXERCISES

1. Draw and describe the alfalfa plants, or any of the above mentioned plants, in all of their parts and make floral diagrams and dissections of the seeds of these important plants.

2. A similar study should be made of the red clover, crimson clover, white clover, cowpea, soy-bean and peanut, or any available leguminous crop plant. All of them, if time permits.

3. Study in detail the fruits and seeds of alfalfa, red clover and peanut, etc. Sections of swollen seeds should be treated with iodine solution and other reagents, as time permits.

4. The members of the class should be instructed to plant unroasted peanuts in pots at home, as the growth of the plant can be watched with great interest and instruction to the students, who undertake to do this.

CHAPTER 16

LEGUMINOUS ROOT TUBERCLES AND THE ACCUMULATION OF NITROGEN; NITROGEN-CONSUMING PLANTS

Loss of Soil Nitrogen.—It is important before considering the accumulation of soil nitrogen, to briefly state how the soil may lose this valuable chemical substance. The nitrogen in the form of ammonia gas may be diffused into the atmosphere, and there is no doubt, but that a very considerable amount of nitrogen is thus dissipated. The soluble ammonia, nitrites and nitrates may be removed from the superficial layers of the soil by drainage into the subsoil, where they usually find their way by percolation of rain-water from above. This loss by drainage is greatest during the late summer and autumn, when the process of nitrification is excessive. This process of nitrification in soils is preceded by putrefaction where the organic materials of the soil are broken down by bacteria and fungi into various end products among them ammonia, which is also formed by the fermentation of the urine of herbivorous animals, according to the reaction:

$$CO(NH_2)_2 + 2H_2O = CO_3(NH_4)_2$$

No less than sixty species of bacteria are said to occur in manure and sewage and a considerable number are able to cause the ammoniacal fermentation of urine.

Nitrification.—Now an entirely different set of organisms come into play. The ammonia is converted by the activity of several species of *Nitrosococcus* and *Nitrosomonas* into nitrous acid, or the corresponding nitrite. The next step in the process of nitrification is the conversion of nitrous acid, or nitrite, into nitric acid, or the corresponding nitrate. This is accomplished by the nitrate bacteria (*Nitrobacter*), which convert the nitrous acid or nitrite into nitric acid, or nitrate.

Here, we have the explanation why Indian corn does not exhaust the soil, as rapidly, as some other crops. The growth of corn extending much further into the late summer and autumn, the plant acts as a catch crop in the utilization of part of the nitrates formed during the active processes of nitrification.

In the third place, the nitrogen is lost to the soil by a chemical union with other soil substances, so as to form insoluble compounds which are, therefore, unavailable to the growing crops. The loss may also be accomplished by denitrification, which is due to the presence in the soil of nitrate-reducing bacteria, which are active, when the soil is wet with standing water and the oxygen supply is poor. Perhaps, the largest amount of nitrogen is removed from the soil in the harvesting and sale of the crops. These harvested crops are carried to our large centers of population, or sent overseas where they are lost, as far, as returning manurial equivalents to the soil of the country in which they were produced, is concerned. Crooks estimates that England alone wastes in the sewage and drainage of her cities, nitrogen to the value of $80,000,000 per year. Hence in the husbanding of our natural resources, the sewage from our large cities should be saved. It is so saved in China and Japan, but the sewage farms, which have been tried, American and European, have not been profitable, hence, the whole matter of sewage disposal by sediment alone and by the septic tank is still open for exhaustive scientific research. Connected with this disposal of sewage, horse and cattle manures is the management of home and local markets, where the produce of our farms might be utilized and the waste products, where suitable, might be returned to the soil.

Having briefly outlined the ways in which the soil becomes impoverished, it is important clearly to state how the nitrogen of the soil may be accumulated. One of the most important sources of supply is barnyard manure, which contains large quantities of ammonia, but that ammonia cannot be absorbed directly by the root hairs of the agricultural plants. We have abundant experimental proof that green plants, except the Leguminosæ, can utilize the nitrogen only in the form of nitrates, or only to a very slight extent in the form of ammoniates. We have noticed how this process of nitrification takes place in two steps by the activity of nitrifying bacteria, whose growth in the soil is stimulated by aeration, by the requisite moisture and a feeble alkaline condition of the soil. Once the ammonia is converted into nitrates, the supplies of nitrogen in the soil become available to green plants. Many plants are independent of this supply of nitrogen in the form of nitrates, viz., the *Leguminosæ* and perhaps some few members of the families *Betulaceae*, *Eleagnaceae* and *Podocarpaceae*, which can utilize free atmospheric nitrogen.

Nitrogen-Storing Plants.—We have, therefore, two classes of agricultural plants: nitrogen-storing plants and nitrogen-consuming plants. The nitrogen-storing plants are those which can utilize the free atmospheric nitrogen. These plants, if the soil is rich in nitrogen, or if the nodules do not form on their roots, become as ordinary nitrogen-consuming plants, *i.e.*, they require nitrogen. When the seeds of clover, or some other leguminous species are planted, soon after the primary roots appear with their root hairs, the nodule producing organisms (*Bacillus* (*Pseudomonas*) *radicicola*) attracted perhaps chemotactically to the fine root hairs, penetrate the walls of these root hairs and enter through these cells into the middle cortex layers of the root. So many organisms enter, that they form a long, slimy cord, almost hypha like. Here in the root cortex cells, the microorganisms form nests, or pockets, that become filled with bacteria. The presence of these rod-shaped bacteria causes the formation of swellings, galls, tubercles, or nodules on the roots of the leguminous plants. Here they remain, utilizing the free atmospheric nitrogen, when stimulated by small amounts of carbohydrates, derived from the green host plant until about the time of flowering of the host, when the bacteria begin to undergo involution changes, enlarging considerably in size and assuming S-shaped, or Y-shaped forms (bacteroids). After this, they are gradually absorbed by the green plants until the tubercle becomes empty—a mere shell. The nitrogenous material has been dissolved and utilized by the leguminous plant in the formation of plant substance, or in the form of reserve food within seeds and other parts of the green host.

Types of Leguminous Nodules.—Although the organism is the same in all leguminous plants, viz. *Bacillus radicicola*, it exists in varietal forms, which are peculiar to each of the important species of leguminosæ being, therefore, polymorphic, although occasional cross inoculations occur (Fig. 95). A recent study of a large number of genera of leguminous plants by Spratt has shown that there are four general types of tubercles: I. The Genisteæ type in which the nodule is primarily spherical, with a spherical meristem outside the bacteroidal tissue, which becomes localized at certain parts, and thus the nodule acquires a very uneven surface and shape. The vascular supply forms one broad zone across the base of the nodule, which subsequently branches and produces a varying number of strands. The bacteroidal tissue becomes separated into a number of distinct areas with a varying amount of sterile tissue between. Plants with this type of nodules are woody. Many are shrubs, *e.g.*, *Genista*, *Ulex*, *Amorpha;*

some are herbs *Lupinus, Ornithopus, Cytisus, Desmodium* and *Laburnum* is a tree. II. The Phaseoleæ and Trifoleæ type with the bacteroidal tissue undivided and central. The growing point at an early stage becomes localized apically, consequently they elongate although remaining very narrow, *e.g., Trifolium,* and frequently the apical meristem

FIG. 95.—Roots of soy bean, showing nodules. (*After Piper, C. V.: Leguminous Crops for Green Manuring. Farmers' Bulletin 278, 1907, p. 20.*)

branches, so that a repeatedly branched nodule may result, *e.g., Lotus corniculatus.* Here belong nodules of *Trifolium, Phaseolus, Coronilla, Lotus, Ononis, Anthyllis.* III. In the Viceæ type, the nodules have the elongated form with a well defined apical meristem and a basal intercalary zone, which produces a small amount of tissue. The nodule frequently branches and may form very large clusters, *e.g.*, *Vicia faba* and *Stizolobium*, but there is one continuous bacteroidal zone, the apical portions of which are traversed by innumerable infection threads. Two vascular strands are produced at a very early stage of the development of the nodule on opposite sides, each of which has a separate attachment to the root stele. This group includes a number of plants of considerable agricultural value viz., *Vicia*, *Pisum*, *Lathyrus*, *Galega*, *Stizololium*, and *Colutea*. IV. The fourth group of nodules occur on plants such as *Robinia*, *Sophora*, *Acacia*, of west temperate and subtropical regions. The nodules all develop two vascular strands, which have a separate attachment to the root bundle system and a well developed bundle sheath is present. In *Acacia*, the nodule is bean-shaped, in *Sophora* and *Robinia*, the nodule is transversely indented, the indentations occurring between two periods of growth. This is the Mimosoideæ type.

The amount of nitrogen which is fixed by *Bacillus radicicola* has been thought to be connected with the quantity of slime which is produced under given conditions. If the formation of slime is great in amount the bacteria are held in it and form a zoogleal thread. It is in this form, that they enter the root hairs and passing from cell to cell finally reach the root cortex. The slime is absorbed and the bacteria live freely in the cell, being transformed into the so-called bacteroids, which are V and Y shaped in such plants as *Vicia faba*, or spherical as in *Lotus corniculutus*. These it is believed are gradually absorbed by the plant. Recently, Erwin F. Smith has called in question many of the accepted theories as to the leguminous nodules, and he cites Gino-de-Rossi, who maintains that a schizomycete of quite different character is the real cause of the nodules. We have given the usually accepted views without presenting the controversial points.

Leaf Nodules of Rubiaceæ.—Recently attention has been called to certain rubiaceous plants *Psychotria bacteriophila* and *Pavetta Zimmermanniana* and probably others, which have small nodules on their leaves, which contain colonies of a non-motile, nitrogen-fixing bacterium named by Faber *Myco-bacterium rubiacearum*. These bacteria almost invariably inhabit the micropyle of the young seed, and, when the latter germinates, grow through certain stomata of the young leaves and into the intercellular spaces formed in the leaf-tissues around these stomata. Cavities are formed through the growth of the epidermal cells which later close entirely and make bacterial nodules which are deeply imbedded in the leaf tissues. A single leaf may have several dozen of these symbiotic bacterial nodules. Faber has shown that the leaves of these rubiaceous plants through the presence of the nodules containing bacteria are able to gather nitrogen like the legumes and store it in the small nodules. As the value of the leaves of these plants in agricultural operations in the tropics has been recognized in India, it has been suggested that these nitrogen-storing members of the *Rubiaceæ* might be grown as subsidiary crops beneath rubber, cocoa and coffee trees and their leaves allowed to accumulate on the ground to serve as a mulch and as a nitrogenous fertilizer. It might be possible to prune the trees and use the clippings as fertilizer.

Use as Green Manure.—When the leguminous crop is mature, or before it is mature, it may be plowed under as green manure. Here in the soil by the process of putrefaction already described, the organic nitrogen of the plant is converted into a form of nitrogen which through the nitrifying bacteria is again converted into a form (nitrate) available to another crop of green plants. Thus the nitrogen cycle is completed. Or, if the leguminous crop is not used as a green manure, but is consumed, it should be used on the farm and not sold off the farm, because transformed by passing through the bodies of the farm animals, it becomes flesh on the one hand and barnyard manure on the other, which can be restored to the soil to help keep up its fertility.

Rotations.—One of the approved methods of agricultural practice is to grow leguminous crops for home consumption, and the non-leguminous, nitrogen-consuming crops for sale. One practical farmer grows mixed crops of leguminous plants, liberally fertilized with potash and phosphoric acid. He converts the first year's crop into silage, which he feeds to his cattle, returning the manure to his soil. He converts the second year's produce into hay. The land thus produces highly nitrogenous crops without purchasing outside supplies of expensive nitrogenous fertilizers, and is left in a high state of fertility for potatos or cereal crops which respond to rich supplies of nitrogen in the soil.

Encouragement of Leguminous Crops.—Having ascertained these facts, the question naturally arises, How can the growth of leguminous plants be encouraged? It has been discovered that leguminous crops require considerable supplies of potash and phosphatic fertilizers. Potash has considerable to do with the metabolism concerned in the formation of carbohydrates, and phosphorus compounds have to do with the nitrogenous metabolism. This fact was impressed upon the writer on a visit to the Rothamsted Experiment Farm in England in 1892. Experiments at Rothamsted have demonstrated that whenever nitrogenous fertilizers were supplied to the plots of herbage, the grasses increased in number and abundance. Whenever potash replaced the nitrogen, the leguminous plants began to invade the experimental plats. The student having followed the above discussion may ask the question, if it is not possible to introduce the proper organism, namely, *Bacillus radicicola* to the soil in order to render more certain the inoculation of the leguminous plants grown either for forage, for human food, or for green manure, as the leguminous plants through the activity of the nodule-forming bacteria are supplied with a source of nitrogen not available to most other plants?

Microbe-Seeding.—Where nitrogen-fixing bacteria are lacking in a soil, it is possible to introduce them artificially either by transferring soil from an old field, where the desired leguminous crop has been grown successfully, or by the use of pure cultures of the proper organism. The method of transferring soil is inconvenient and expensive, and the use of the preparation nitragin has not been a success. The organisms grown upon nitrogen-free media have been found beneficial, if added directly to the soil, although negative results are obtained, if the soil already contains the proper bacteria, or if the soil is acid, needs fertilizers, such as potash, phosphoric acid, or lime, and is so rich in nitrogen as to prevent the development of the nitrogen-fixing organism.

Nitrogen-consuming Plants.—The point of interest to remember is that the preceding leguminous, nitrogen-storing crop prepares the soil, if used as a green manure, for the succeeding nitrogen-consuming crops, which need their nitrogen in the form of nitrates. Agriculturally speaking there are eight groups of nitrogen-consuming plants which may be distinguished: the root, bulb, stem, leaf, flower, fruit, seed, and cereal crops. All of these crops need nitrogenous substance for their best development, because sugar, starch and other carbohydrate reserve materials are only stored in the plant when nitrogen is present in efficient supplies. The proper storage of the various carbohydrates can take place only when the storage cells are supplied with the requisite amounts of nitrogen and potash. If the plant is nitrogen hungry, such carbohydrate reserve supplies are not formed. As a large number of plants used by man and grown in various parts of America in horticultural and agricultural operations have been omitted purposely in order to keep this book within bounds, an enumeration of these nitrogen-consuming plants will be made here.

Root Crops

The root crops are those which represent the underground root, or stem of the plant which is cultivated. Enumerated the plants are:

Potato (*Solanum tuberosum*), a native of America and cultivated for its enlarged, starch-filled tubers.

Sweet Potato (*Ipomoea batatas*) originally from the West Indies and Central America. It is cultivated for its fleshy roots filled with starch.

Radish (*Raphanus sativus*) is a native of the temperate regions of the old world and is raised for its fleshy tap root.

Horse-radish (*Radicula armoracia*).—This plant is a native of Europe and has a white, fleshy, cylindrical root, which is grated and used as a condiment.

Turnip (*Brassica napus*).—The turnip is a biennial plant producing an edible, fleshy tap-root. It is a native probably of Europe, or Western Asia.

Rutabaga, or **Swede Turnip** (*Brassica campestris*).—The fleshy edible root has a short stem, or neck, at its upper part which distinguishes it from the turnip. It is used as food for stock and occasionally as food for man.

Beet (*Beta vulgaris*).—This is a complex species separated into several well-marked groups, as the sugar beet, mangel-wurzels and common garden beet. The wild beet occurs along the coasts of southern Europe as a perennial sea beet (*Beta maritima*) with a tough, slender root.

Jerusalem Artichoke (*Helianthus tuberosus*).—The thick, fleshy root-stocks with oblong tubers are the parts used as food. This native American plant is also called earth apple, Canada potato, girasole and topinambour.

Carrot (*Daucus carota*).—The conical root of the carrot is an important food. The carrot is a biennial plant native of Europe and Asia.

Parsnip (*Pastinaca sativa*).—The fleshy root of the cultivated plant has been developed from a thin, tough, woody root and hypocotyl. It is a native of Europe.

Celeriac (*Apium graveolens*).—This vegetable is the turnip-like root of the celery plant, originally a wild plant of Europe.

Salsify (*Tragopogon porrifolius*).—This plant is grown for its fleshy roots which have an oyster flavor.

Chorogi (*Stachys Sieboldii*).—The Chinese, or Japanese artichoke is a mint-like plant with crisp tubers eaten raw, or cooked.

Ulluco (*Ullucus tuberosus*).—This plant is a native of Peru, where it is cultivated for its tubers.

Chufa (*Cyperus esculentus*).—The edible tubers of this sedge are much prized in the south, where it is often cultivated. The raw, or baked chufas have an agreeable nutty flavor.

Ginger (*Zingiber officinale*).—The rhizomes of this tropical plant are cultivated.

Taro, or Dasheen (*Colocasia antiquorum var. esculenta*).—This is the elephant's ear of our gardens. It has been grown as taro from time immemorial by the South Sea Islanders, as one of their important food plants. It has been lately grown in the United States for its large starchy corms and its leaves under the name of dasheen.

Eddo, Tannia, Yautia, Cocœ (*Xanthosoma atrovirens*).—The underground tubers are edible.

Cassava (*Manihot utilissima*).—This plant is also called bitter cassava, mandioca, manioc, tapioca plant. It is the chief food of the tropical Indian tribes of South America, where maize is not grown. Cassava is cultivated for its starchy roots in many parts of the tropics, since it is a crop which yields large return for a comparatively small amount of labor.

Yam (*Dioscorea alata* and *D. batatas*).—The yam is much cultivated in countries with a warm climate for its large, mealy, or starchy roots, which are used much like sweet potatoes.

Arracacha (*Arracacha esculenta*).—This is a plant allied to the parsnip and carrot and is extensively cultivated in the Andes. It has become naturalized in Jamaica.

Bulb Crops

Chia-peh-ho (*Lilium tigrinum*).—The bulbs of this lily with a parsnip flavor are eaten in China.

Onion (*Allium cepa*).—The cultivation of the onion dates back to the earliest times in the history of China, Egypt and India. Its bulbs are large and show many varietal differences due to manner of propagation, quality, shape, color, size and time of maturity (Fig. 96).

Garlic (*Allium sativum*).—This plant is a native of southern Europe.

Leek (*Allium porrum*).—A robust biennial plant with small bulbs, native of the Mediterranean region.

Chives (*Allium schœnoprasum*).—A hardy perennial plant bearing small, narrowly ovoid, clustered bulbs with membranous coats. It is a native of Europe, Asia and North America.

Shallot (*Allium ascalonicum*).—The bulbs are borne in clusters, but unlike garlic are not surrounded by a thin membrane.

Welsh Onion, or Ciboule (*Allium fistulosum*).—This is an annual, or biennial plant with long fibrous roots without bulbs, but the base of the plant is swollen. It grows wild in the Altai mountains and about Lake Baikal in Siberia.

STEM CROPS

Asparagus (*Asparagus officinalis*).—The stems of this liliaceous plant are annual arising from fleshy, perennial roots and rootstocks. The young shoots are used as a vegetable. Asparagus is wild in Asia and Europe (Fig. 97).

Sugar Cane (*Saccharum officinarum*). The stems of this perennial grass are one of the chief sources of commercial sugar. It is extensively cultivated in the tropics.

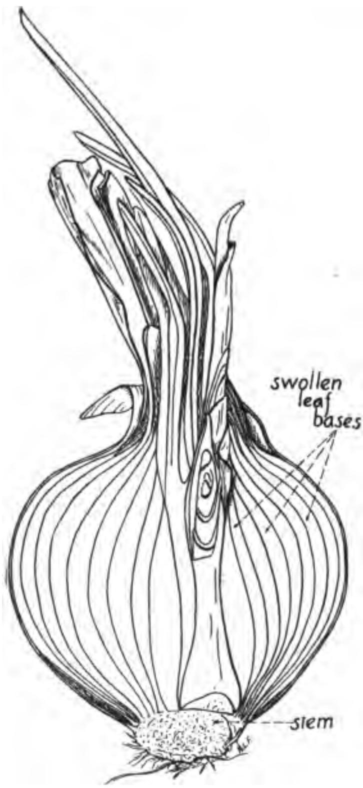


FIG. 96.—Median lengthwise section of common onion bulb. (*Robbins*.)

Bamboo (*Bambusa arundinacea*, *B. vulgaris*) and (*Arundinaria nitida*). The shoots of the bamboo are eaten in China in the fresh, dried and salted condition. They are also canned for the export trade.

Kohl-rabi (*Brassica oleracea* var. *caulo-rapa*).—The enlarged basal part of the cabbage stem is eaten as a vegetable under the above name.

Udo (*Aralia cordata*).—The blanched stems of this plant introduced into the United States in 1903 from Japan by Lathrop and Fairchild are used as a vegetable.

Flax (*Linum usitatissimum*).—The bast fibers in the stem of the flax are used for the making of linen fiber.

Hemp (*Cannabis sativa*).—This plant is cultivated in Europe, Asia and the United States for the valuable bast fibers of its stem, which are made into cordage.

Jute (*Corchorus capsularis* and *C. olitorius*).—This plant is grown in Asia for the fibers obtained from its stem by retting.

Ramié (*Boehmeria nivea*).—The fibers of the stem are usually obtained in China by a slow and expensive extraction by hand.

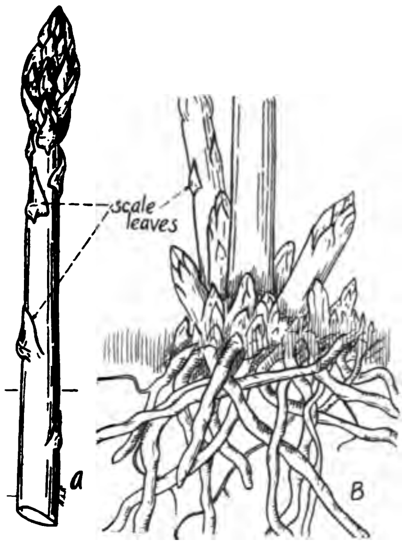


FIG. 97.—Garden asparagus (Asparagus officinalis). *A*, young shoot or "spear"; *B*, thick, fibrous roots and young shoots arising from "crown." (*Robbins.*)

Rubber (*Hevea brasiliensis*).—This the Para rubber tree is cultivated in some tropical countries for its latex, or milky juice, which is converted into rubber.

Castilloa elastica.—A tree of Central America yields Panama rubber and the guayule (*Parthenium argentatum*) is a desert shrub of Mexico from which rubber has been extracted. The Assam rubber is obtained from a tropical fig (*Ficus elastica*) much cultivated indoors in temperate climates for its foliage.

Cinchona (*Cinchona calisaya*).—The bark of this tree yields quinine.

LEAF CROPS

Cabbage (*Brassica oleracea* var. *capitata*).—The leaves of the wild plant from the seashore of southwestern Europe are enlarged and massed together to form a head.

Kale and Collard (*Brassica oleracea* var. *viridis*).—Collards are much grown in the south particularly Georgia. The stem is branched and leafy with broad leaves.

Brussels Sprouts (*Brassica oleracea* var. *gemmifera*).—The axillary buds of this variety of cabbage plant have increased in number along the stem and form small rounded heads, or "sprouts."

Peh-ts'ai (*Brassica chinensis*).—The Chinese cabbage attains its perfection in the colder parts of China. It has recently been introduced into cultivation in the United States.

Lettuce (*Lactuca sativa*).—There are several varieties of lettuce, which are cultivated for their leaves, which are used for salad. The cos lettuce and head lettuce are the most common.

Endive (*Cichorium endivia*).—The leaves of this plant are used as greens, as also those of the closely related succory (*C. intybus*).

Celery (*Apium graveolens*).—The blanched, basal sheath of the leaves and the petioles represent the market celery. The plant was originally cultivated in Europe.

Parsley (*Apium petroselinum*).—The leaves, which are gathered for use as a pot herb, are plain, or curled.

Rhubarb (*Rheum rhaponticum*).—The use of the succulent leaf stalks for stewing and for tarts is widespread.

Dasheen (see under root crops).

Spinach (*Spinacia oleracea*).—The leaves of this are much in demand for greens. It is a native of southwestern Asia and in China is called po-ts'ai.

New Zealand Spinach (*Tetragonia expansa*).—The tender leaves and tips of the stem are used for greens.

Tea (*Camellia Thea*).—The young leaves of this shrub are gathered and dried for export from the various warm temperate countries where tea is grown as a commercial crop. The industry is an enormous one in China.

Maté (*Ilex paraguayensis*).—The leaves of this shrub are used as a popular beverage in several South American countries.

Coca (*Erythroxylon coca*).—The leaves of this South American shrub are universally chewed by the Indian men and women, because they have stimulating effect and prevent tissue waste.

Tobacco (*Nicotiana tabacum*).—The large leaves of this American plant are cured and made into cigars, cigarettes, chewing and smoking tobacco.

Manila Hemp (*Musa textilis*).—The leaf fibers of this species of banana are made into Manila hemp one of the chief exports from the Philippine islands.

Pita (*Agave americana*).—The maguey grows on the plateaus of Mexico, and its leaves yield the valuable Pita fiber.

Sisal (*Agave sisalana* and *Agave rigida* var. *sisalana*).—The sisal fiber is exported in large quantities from Yucatan in Mexico.

New Zealand Flax (*Phormium tenax*).—The plant which yields this fiber grows wild in New Zealand and neighboring islands where it was used by the native Maoris.

Bowstring Hemp (*Sansevieria cylindrica*).—The natives of South Africa, where this plant grows, make their bowstrings from the leaf fibers.

Medicinal Leaves.—The following are some of the important medicinal leaves: rosmary, thyme, eucalyptus, senna, coca, belladonna, digitalis, buchu, and aconite.

Flower Crops

Cauliflower, Broccoli (*Brassica oleracea* var. *botrytis*).—These are types of cabbage plant in which there is a large head composed of abortive flowers upon very much modified, thickened flower stems (Fig. 98).

Artichoke (*Cynara scolymus*).—The fleshy involucral bracts and the fleshy receptacle of the heads of this compositous plant are used as a vegetable.

Yeh-peh-ho (*Lilium Sargentiæ*).—The flowers of this lily are eaten in China after being boiled, dried in the sun, minced, fried with salt and oil eaten in the same way as preserved cabbage.

Huang-hua-ts'ai (*Hemerocallis flava.*)—The flowers of the yellow day lily are eaten by the Chinese.

Flowers for Perfume.—In the provinces of southern France as at Grasse, flowers are raised commercially for the manufacture of the various extracts and perfumes in universal demand by civilized men. The flowers of roses, violets, jasmine and orange are so used.

Insect Powders.—Insect powder is made from the finely ground flower heads of *Chrysanthemum pyrethrum*. Dalmatian insect powder comes from *Chrysanthemum cinerariæfolium* and Persian from *C. roseum*.

FIG. 98.—Cauliflower (*Brassica oleracea botrytis*). *A*, entire plant; *B*, portion of "head. (*Robbins*.)

FRUIT CROPS

Temperate Lands

Apple (*Pyrus malus*).—The apple is cultivated extensively in a great many varieties in America, Asia and Europe.

Pear (*Pyrus communis*).—The common pear is probably a native of southern Europe and Asia with a fruit usually tapering to the base and a flesh with grit cells.

Quince (*Cydonia oblonga*).—The quince tree produces a fruit hairy when young, becoming smoother with age. The skin is yellow at maturity and the seeds are surrounded by a mucilaginous covering.

Plum (*Prunus*).—This genus includes a number of species of trees which yield a plum-like fruit.

Sweet Cherry (*Prunus avium*).—The sweet cherry is produced on a tall European tree, which has been cultivated in America for many years.

Sour Cherry (*Prunus cerasus*).—The tree which produces the sour cherry is smaller than the sweet cherry tree, but like it it is a native of Europe.

Apricot (*Prunus armeniaca*).—This species is considered to be a native of southern Asia.

Peach (*Prunus persica*).—The peach tree is probably a native of China and was long ago introduced into Europe and later America through central Asia.

Almond (*Prunus amygdalus*).—The almond is cultivated for its kernel with seed, therefore the outer fruit coats are fibrous and not fleshy as in the peach with which the almond is closely related.

Olive (*Olea europæa*).—The olive tree with evergreen, grayish-green foliage is a native of the Mediterranean region, where it has been cultivated since ancient times.

Ash Pumpkin (*Benincasa cerifera*).—A large, handsome, oval-shaped gourd grown throughout China and Japan.

Water-melon (*Citrullus vulgaris*).—This fruit because of its refrigerant pulp is deservedly popular in late summer.

Melon (*Cucumis melo*).

Native Cucumber (*Cucumis sativus*).—The fruit is usually peeled, sliced and served in vinegar.

Pumpkin (*Cucurbita pepo*).—The fruit of this annual species has a ribbed usually reddish-orange rind.

Squash (*Cucurbitia maxima*).—There are several kinds of squashes, such as the turban, Hubbard, Marblehead and marrow squashes.

Cantaloupe (*Cucumis melo*).—The true cantaloupes are usually deep-ribbed, hard-rinded and warty, or scaly.

Tomato (*Lycopersicum esculentum*).—The fruit of this short-lived perennial of the family *Solanaceæ* used to be considered poisonous and was known then as love-apple. It is now one of our most important fruit vegetables.

Egg Plant (*Solanum melongena*).—The fruit is a large, purple-skinned, pear-shaped one used in the baked form or sliced and fried either with or without bread-crubs.

Pepper (*Capsicum annuum*).—The fruit is red or green color and exists in a number of varieties prized for their pungency.

Fig (*Ficus carica*).—The fig is cultivated to some extent in the southern and southwestern United States and Mexico, where its fresh fruit may be obtained. The cured and pressed figs are found on the fruit stands of all large American cities.

Mulberry (*Morus alba, M. nigra, M. rubra*).—These trees are sometimes cultivated for their multiple juicy fruits.

Date (*Phœnix dactylifera*).—The finer varieties of date from the desert regions of North Africa have been introduced recently into the United States, where their cultivation in Arizona and southern California has become an established fact.

Persimmon (*Diospyros virginiana* and *D. kaki*).—The finer cultivated persimmons came to us from Japan, where the fruit is much relished.

Currant (*Ribes rubrum*).—This species includes all of the red and white fruited currants. The black currant of Europe is *R. nigrum*, the wild black currant of America is *R. americanum* and the flowering currant *R. aureum.*

Gooseberry (*Ribes grossularia* and *Ribes oxyacantha*).—The first named gooseberry is European with a rough hairy or prickly fruit, the second species is American with a smooth fruit.

Blackberry (*Rubus nigrobaccus*).—The tall stems of this plant are armed with strong, hooked prickles. The plant grows in the eastern United States and has sweet, aromatic fruit.

Dewberry (*Rubus trivialis* and *R. villosus*).—The first species is southern and the last grows in the north. Both have been introduced into cultivation.

Raspberry (*Rubus occidentalis* and *R. strigosus*).—The first mentioned species is the black raspberry and the second the red raspberry. Both are native of America.

Strawberry (*Fragaria*).—Three species must be considered as the cultivated ones. The early settlers in the eastern United States cultivated the wild strawberry (*Fragaria virginiana*). Attempts have been made to grow the European strawberry (*Fragaria vesca*), but it has been limited. Most of our cultivated strawberries belong to the species, *F. chiloensis* (Fig. 99).

Grape (*Vitis*).—The old-world grape is *Vitis vinifera*. The muscadine grapes, or southern fox grapes are *Vitis rotundifolia*, one of the chief varieties of which is the Scuppernong. The northern fox grape (*V. labrusca*) has given us the Concord, one of the best grapes grown.

Okra (*Hibiscus esculentus*).—The capsule of this plant is rich in mucilage, hence, the fruit is a favorite one to thicken soup.

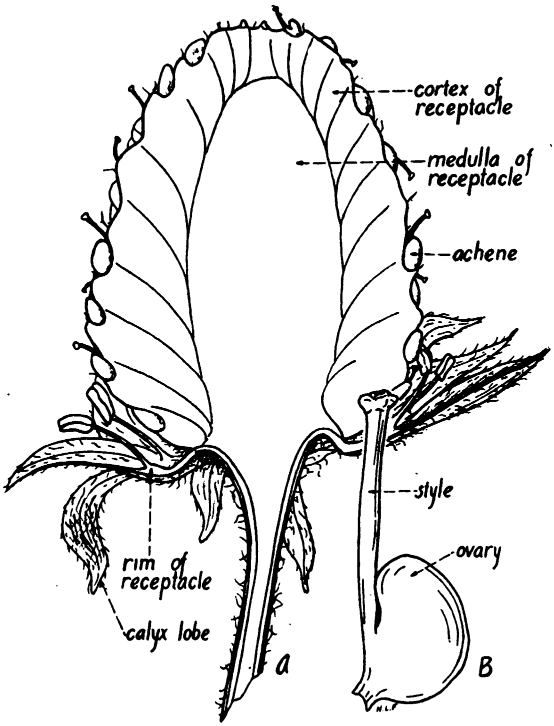


Fig. 99.—Strawberry (*Fragaria chiloensis*). *A*, "fruit" in median length-wise section $\times 2\frac{1}{2}$; *B*, single achene, $\times 20$. (*Robbins*.)

Blueberry (*Vaccinium corymbosum*).—Since the discovery that this swamp shrub can be grown in an acid peat, hopes have been raised that superior table fruits may be derived from the large, sweet, wild fruit.

Cranberry (*Vaccinium macrocarpon*).—The trailing plant, which yields the cranberry, so much used in the making of a jelly-like sauce, is grown extensively on Cape Cod, in New Jersey and in Michigan.

Tropical Fruits

Citron (*Citrus medica*).—The commercial citron is the dried fruit of this species. It is also candied.

Lemon (*Citrus limonia*).—The lemon tree is a native of India and its fruits yield a sour juice used in the making of lemonade.

Lime (*Citrus aurantifolia*).—The small greenish fruits are borne on a small straggling tree.

Sweet Orange (*Citrus sinensis*).—The concensus of opinion as to the home of the wild orange is southeastern China.

King Orange (*Citrus nobilis*).—The fruit of this tree is rarely seen in the city fruiterers. A variety is known as the mandarin orange.

Grapefruit, Shaddock, Pomelo (*Citrus grandis*).—The large yellow fruits of this species have become an almost indispensable fruit for the breakfast table.

Sour Orange (*Citrus aurantium*).—This species is now much used for budding and grafting the better varieties of citrus plants upon.

Pineapple (*Ananas sativus*).—The multiple, juicy fruit of this plant is borne in the center of a rosette of spiny, rigid, leathery leaves. The fruit is eaten fresh, or canned.

Custard-apple (*Annona squamosa*). The tree which produces this fruit with a white granular, sweet custard-like pulp is a native of Asia and tropical America.

Bread-fruit (*Artocarpus incisa*).—The fruit is large and is roasted in the tropics as a vegetable. The leaves of the tree are glossy and pinnately incised.

Papaw (*Carica papaya*).—The hollow fruit of this plant with yellowish pulp has digestive properties and is used to assist digestion in the tropics.

Durian (*Durio zibethinus*).—The tuberculate fruit of this tree is relished by some, as resembling blanc-mange, delicious as the finest cream. The bad odor of this fruit causes some people to avoid eating it. The name civet-cat fruit is suggestive of its smell.

Mango (*Mangifera indica*).—The delicious fruit of this tree has been likened to a piece of cotton soaked with turpentine, as the flat seeds are usually covered with a dense hairy covering. Improved kinds are grown.

Plantain, or Banana, (*Musa sapientum*).—This is one of the principal tropical fruits cultivated in extensive plantations and shipped to northern ports. The trade is enormous.

Alligator Pear (*Persea gratissima*).—The tree, which yields a smooth skinned fruit, is cultivated in Florida and elsewhere in the tropics.

Cereal Crops

This group includes the caryopses of maize, wheat, rye, barley, oats, rice, wild rice, and others previously described in detail, and in addition the following, which were not described, because of the want of space for a proper presentation of their botany and usefulness: the sorghums (*Andropogon sorghum*) include the cereals sorgo, kafir, milo, broom corn, shallou, kowliang, durra and the millets: pearl millet (*Pennisetum glaucum*), proso, hog, or broom-corn millet (*Panicum miliaceum*), the foxtail millet (*Chaetochloa italica*), the barnyard millet (*Echinochloa crus-galli*) and the Japanese barnyard millet (*Echinochloa frumentacea*). The foxtail millet (*Chaetochloa italica*) includes the types Hungarian, Aino, German, Siberian, Golden Wonder and common millets. The bibliography given later will enable the student to become acquainted with them. See following bibliography under "additional cereal and grain crops."

Seed Crops

Cotton (*Gossypium barbadense* and *G. herbaceum*).—These two species are literally cultivated for their seeds for after the removal of the twisted hairs from the surface of the seed coats, the seeds are ground and yield a table oil and a cake used as a cattle feed.

Coffee (*Coffea arabica*).—The seeds are taken from the fruit, decorticated and roasted before being used to make one of the favorite beverages of civilized man.

Cocoa. (*Theobroma cacao*).—The seeds of this tree are found in large, ribbed capsules. They are removed, dried and are ground for use in making chocolate by the addition of sugar.

Coconut (*Cocos nucifera*).—The fruit of this palm is a drupe with a large, fibrous covering inclosing the so called nut, the shell of which (the endocarp of the fruit) has 3 germ pores. The shell incloses the large seed, the endosperm of which inclosing the embryo, contains an abundance of oil. The ditect endosperm is exported as copra and from copra is extracted the oil used in the making of soap.

Flax ((*Linum usitatissimum*).—From the seeds of the flax is obtained by expression, linseed oil.

Castor Oil ((*Ricinus communis*).—The medicinal castor oil obtained from the seeds of this plant has strong laxative properties. There was a great demand during the late world war for castor oil as a lubricant for aeroplanes.

Quinoa (*Chenopodium quinoa*).—The small, round, white seeds of this South American plant are used as a food.

Betel (*Areca catechu*).—The seeds of this palm are gathered in India and elsewhere for use as a masticatory, or chewing material. The seeds are sliced and rolled up with lime in leaves of the betel pepper. The teeth of the consumer are stained with the juice.

Modern experiments prove that the production of the nitrogen-consuming plants (root crops, bulb crops, stem crops, leaf crops, flower crops, fruit crops, seed crops, cereal crops, as above) should be alternated with the cultivation of the nitrogen-storing plants, such as alfalfa, clover, beans, cowpeas, soy-beans, lupines, which accumulate atmospheric nitrogen by the agency of the bacteria in their root nodules. With a view to emphasizing this fact as we have proceeded with our descriptions approved rotations have been given for various crop plants in which rotations the leguminous plants have prominently figured. Progressive farmers should grow-nitrogen accumulating plants for home consumption and nitrogen-consuming crops for sale and removal from the farms where produced, either to home, or to foreign markets. This system should be extended so as to comprehend the whole country in a complete and perfect system of rotation. It will bring about a diversification of agricultural industries, so as to permit the cultivation of the crops best adapted to the climate and soil zones of America and other countries.

Bibliography

Allen, E. W.: Leguminous Plants for Green Manuring and for Feeding. Farmers' Bulletin 16, U. S. Department of Agriculture, 1894.

Cameron, S. C. R.: The Wild Foods of Great Britain where to Find Them and how to Cook Them. London, George Routledge & Sons, Ltd., 1917.

Collins, S. H.: Plant Products and Chemical Fertilizers. New York, W. Van Nostrand Company, 1919.

Dodge, Charles Richards: Flax for Seed and Fiber in the United States. Farmers' Bulletin 27, 1895.

Duggar, J. F.: Sweet Potatoes: Culture and Uses. Farmers' Bulletin 26, 1895.

Drews, George J.: Unfired Foods and Trophotherapy. Chicago, 1919.

Fischer, Alfred: The Structure and Functions of Bacteria. Oxford at the Clarendon Press, 1900, 88–106.

Freeman, W. G., Chandler, S. E. and Henry, T. A.: The World's Commercial Products. Boston, Ginn and Company, 1911.

Hall, A. D.: The Book of Rothamsted Experiments. New York, E. P. Dutton and Co., 1905.

Harshberger, John W.: The Accumulation of Soil Nitrogen. Bulletin 151, Department of Agriculture of Pennsylvania, 1906, 76–84, Proceedings of the Spring Meeting of the State Board of Agriculture and Farmers' Annual Normal Institute held in the Court House, Clearfield, Penna., May 29 to 31, 1906; A Text Book of Mycology and Plant Pathology. Philadelphia, P. Blakiston's Son & Co., 1917; 28–31; Maize: A Botanical and Economic Study. Contributions from the Botanical Laboratory, University of Pennsylvania, 1, 189–198, 1893. American Food Plants, Past and Present. Public Lectures, University of Pennsylvania, v: 215–232, 1917–1918.

Kellerman, Karl F. and Robinson, T. R.: Inoculation of Legumes. Farmers' Bulletin 240, U. S. Department of Agriculture, 1905; Progress in Legume Inoculation. Farmers' Bulletin 315, 1908.

Kephart, Horace: The Book of Camping and Woodcraft. A Guidebook for those who Travel in the Wilderness. New York, The Outing Publishing Company, 1909, pages 217–255.

Lawes, John B. and Gilbert, J. Henry: The Battle in the Meadow. Gardeners' Chronicle, new ser., xii, 390, Sept. 27, 1879.

Lipman, Jacob G.: Bacteria in Relation to Country Life. New York, The MacMillan Company, 1908.

MacMillan, H. F.: A Handbook of Tropical Gardening and Planting. Second edition, H. W. Cave & Co., Colombo, 1914.

Maisch, John M.: A Manual of Organic Materia Medica. Third edition, Philadelphia, Lea Brothers & Co., 1887, 209–252.

Moore, George T.: Soil Inoculation for Legumes. Bulletin 71, Bureau of Plant Industry, U. S. Department of Agriculture, 1905.

Moore, George T. and Robinson, T. R.: Beneficial Bacteria for Leguminous Crops. Farmers' Bulletin 214, U. S. Department of Agriculture, 1905.

Piper, C. V.: Leguminous Crops for Green Manuring. Farmers' Bulletin 278, 1907.

Robbins, Wilfred W.: The Botany of Crop Plants. Philadelphia, P. Blakiston's Son & Co., 1917.

Saunders, Charles F.: Useful Wild Plants of the United States and Canada. New York, Robert M. McBride & Co., 1920.

Smith, Erwin F.: Bacteria in Relation to Plant Diseases. Volume 2, 1911, 97–146.

Spratt, Ethel R.: A Comparative Account of the Root-nodules of the Leguminosæ. Annals of Botany, cxxx, 189–199, April, 1919.

Wiley, H. W.: The Sugar Beet. Farmers' Bulletin 52, 1897.

Wilson, E. H.: A Naturalist in Western China with Vasculum, Camera and Gun. New York, Doubleday, Page & Co., 11, 48–63, 1913.

Winslow, Charles Edward Amory: Protection of River and Harbor Waters from Municipal Wastes. Guide Leaflet 33, American Museum of Natural History, April, 1911.

Additional Cereal and Grain Crops

Babcock, F. Ray: Cereal Experiments at the Williston Station. Bulletin 270, U. S. Department of Agriculture, 1915.

Babcock, F. Ray and Smith, Ralph W.: Grains for Western, North and South Dakota. Farmers' Bulletin 878, U. S. Department of Agriculture, 1917.

Ball, Carleton R.: The History and Distribution of Sorghum. Bulletin 175, Bureau of Plant Industry, 1910; The Important and Improvement of the Grain Sorghums. Bulletin 203, Bureau of Plant Industry, 1911; Better Grain-sorghum Crops. Farmers' Bulletin 448, 1911; The Kaoliangs: a New Group of Grain Sorghums. Bulletin 253, Bureau of Plant Industry, 1913.

Ball, Carleton R. and Hastings, Stephen H.: Grain-sorghum Production in the San Antonio Region of Texas. Bulletin 237, Bureau of Plant Industry, 1912.

Ball, Carleton R. and Leidigh, Arthur H.: Milo as a Dry-land Grain Crop. Farmers' Bulletin 322, 1908.

Ball, Carleton R. and Rothgeb, Benton E.: Kafir as a Grain Crop. Farmers' Bulletin 552, 1913; Uses of Sorghum Grain. Farmers' Bulletin 686, 1915; How to Use Sorghum Grain. Farmers' Bulletin 972, 1918; Grain-sorghum Experiments in the Panhandle of Texas. Bulletin 698, U. S. Department of Agriculture, 1918.

Breithaupt, L. R.: Grains for the Dry Lands of Central Oregon. Farmers' Bulletin 800, 1917.

Champlin, Manley: Experiments with Wheat, Oats and Barley in South Dakota. Bulletin 39, U. S. Department of Agriculture, 1914.

Chilcott, E. F., Griggs, W. D. and Burmeister, C. A.: Corn, Milo and Kafir in the Southern Great Plains Area: Relation of Cultural Methods to Production. Bulletin 242, U. S. Department of Agriculture, 1915.

Clark, J. Allen: Cereal Experiments at Dickinson, N. Dak. Bulletin 33, U. S. Department of Agriculture, 1914.

Dillman, A. C.: Breeding Millet and Sorgho for Drought Adaptation. Bulletin 291, U. S. Department of Agriculture, 1916.

Donaldson, N. C.: Cereal Experiments at the Judith Basin Substation, Moccasin, Mont. Bulletin 398, U. S. Department of Agriculture, 1916.

Hastings, Stephen H.: The Importance of Thick Seeding in the Production of Milo in the San Antonio Region. Bulletin 188, U. S. Department of Agriculture, 1915.

Jones, Jenkin W.: Cereal Experiments on the Cheyenne Experiment Farm, Archer, Wyo. Bulletin 430, U. S. Department of Agriculture, 1916.

Kellerman, Karl F.: A New Source of Plant Food, the Nodules on the Rubiaceous Plants. Journal of Heredity, x, 307, October, 1919.

Letteer, C. R.: Growing Grain Sorghums in the San Antonio District of Texas. Farmers' Bulletin 965, 1918.

Robbins, Wilfred W.: The Botany of Crop Plants. P. Blakiston's Son & Co., 1917.

Ross, John F. and Leidigh, A. H.: Cereal Experiments in the Texas Panhandle. Bulletin 283, Bureau of Plant Industry, 1913.

Rothgeb, Benton E.: Standard Broom Corn. Farmers' Bulletin 958, 1918; Shallu or "Egyptian Wheat." Farmers' Bulletin 827, 1917; Dwarf Broom Corn. Farmers' Bulletin 768, 1916.

SALMON, CECIL: Cereal Investigations on the Belle Fourche Experiment Farm. Bulletin 297, U. S. Department of Agriculture, 1915.
SCOTT, GEORGE A.: The Feeding of Grain Sorghums to Live Stock. Farmers' Bulletin 724, 1916.
SHANTZ, H. L.: National Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area. Bulletin 201, Bureau of Plant Industry, 1911.
STEPHENS, DAVID E.: Experiments with Spring Cereals at the Eastern Oregon Dry-farming Substation, Moro, Ore. Bulletin 498, U. S. Department of Agriculture, 1917.
VINALL, H. N.: Sudan Grass as a Forage Crop. Farmers' Bulletin 605, 1914.
WARBURTON, C. W.: The Non-saccharine Sorghums. Farmers' Bulletin 288, 1907.
WILLIAMS, THOMAS A.: Millets. Farmers' Bulletin 101, 1899.

LABORATORY WORK

Suggestions to Teachers.—The teacher should make a collection of the root systems of a number of the leguminous plants, such as the alfalfa, red clover, alsike clover, crimson clover, white clover, sweet clover, soy-bean, cowpea, peanut, bonavist, kudzu vine and others. Part of the material so collected should be fixed with chrom-acetic acid, or some other fixative, passed up into 50 per cent. alcohol, where it should be kept until it is prepared for paraffin sectioning. The other material of similar nature should be kept in 70 per cent. alcohol.

LABORATORY EXERCISES

1. Draw a comparative series of the tubercles or nodules, of such plants as the alfalfa, red clover, white clover, soy-bean, cowpea and kudzu vine.
2. With a razor make a thin section through each of the nodules above mentioned and draw the arrangement of the bacterial cells and vascular distribution with reference to the rootlet on which the nodule arises.
3. Stain and mount in balsam, paraffin sections of two or three of the tubercles of two or three of the above mentioned plants. Study and draw with the high powers of the microscope.

CHAPTER 17

WEEDS AND WEED CONTROL

Definition.—"A weed is a plant out of place." This is a short concise definition, easily remembered by students. "Any useless, or troublesome plant" is another definition, which has been given and in addition longer definitions have been formulated, as follows: "Every plant which grows in a field other than that of which the seed has been (intentionally) sown by the husbandman is a weed." "Any plant which obtrusively occupies cultivated, or dressed ground, to the exclusion or injury of some particular crop intended to be grown" is another statement. "Thus, even the most useful plants may become weeds, if they appear out of their proper place. The term is sometimes applied to any insignificant looking or unprofitable plants which grow profusely in a state of nature, also to any noxious, or useless plant." "Weeds are plants which tend to take prevalent possession of soil used for man's purposes, irrespective of his will; and, in accordance with usage we may restrict the term to herbs."

Absolute and Relative Weeds.—Weeds may be divided into two classes; absolute weeds and relative weeds. An absolute weed is one which has no recognized use, as the horse nettle (*Solanum carolinense*). A relative weed is one which may be extremely useful to man, but becomes a weed when out of its proper place. The Johnson grass of the south is an example. It is a very nutritious and valuable grass, if kept under control, but if allowed to seed, it spreads rapidly into new ground and becomes extremely troublesome and difficult to eradicate.

Injurious Nature of Weeds.—Weeds are injurious to man for the following reasons.

1. They crowd other plants. Two plants cannot occupy the same ground at the same time, and if weeds are abundant, they occupy the soil to the exclusion of the cultivated plants.

2. They rob the soil of moisture. This may not be harmful, if the soil water is abundant, but when the supplies of water are reduced during dry weather, the weeds transpire through their leaves undue amounts of the precious liquid. Cultivation of the soil under such conditions is

beneficial, because it destroys the weeds, as water-robbers, and secondly, it forms a dust mulch.

3. Weeds absorb the mineral and other food materials upon which the crop brought, into competition with weeds, depends. If the weeds are plentiful, very considerable amounts of food substance are removed from the soil and are thus not available to the planted crop.

4. Certain weeds like the morning-glory and bindweed prostrate the cultivated plants by climbing up them and by their weight causing the growing crop plants to fall over.

5. The weedy plants form fruits and seeds, which become mixed with those of the growing economic plants, and are difficult to remove in the cleaning of such seeds for market. Corn-cockle becomes mixed with wheat, chickweed with alfalfa seeds and the like. Such weed seeds are impurities and lower the agricultural and commercial value of such economic seeds.

6. Weeds, as the host plants of injurious crop insects, harbor the insects from planting time to planting time of the crop plants on which they prey. The injurious Colorado beetle, which destroys the potato, lives on the hedge mustard, thistles, goose-foot and other weedy herbs.

7. Weeds are injurious because they harbor parasitic fungi. The finger-and-toe organism of the turnip lives on the charlock as a weed. The white rust of cabbages (*Cystopus candidus*) is found on the shepherd's purse.

8. Weeds interfere with the proper cultivation of the soil, as their presence mechanically obstructs the use of plow and harrow.

9. It has been suggested without proof that weeds may poison the soil, so as to inhibit the growth of other plants. This relation has not been properly investigated.

10. The roots of weeds penetrate the interior of the drains causing a stoppage, which can be removed only with difficulty.

11. Weeds are unsightly and objectionable because of their smell, rankness and prickly fruits, etc.

12. Weeds are injurious to man and the domestic animals because they are poisonous. This topic has been dilated upon in the earlier chapters of this book and need not be discussed here.

13. Weeds sometimes render hay and other harvested crops of less financial value, and frequently reduce the yield, so that the financial returns may be such that the crop is grown at a serious monetary loss.

14. The presence of weeds in such abundance as to attract attention reduces the selling value of the land on which they are found.

Introduction and Distribution

If the list of American weeds is scanned carefully and analytically, it will be found that most of the injurious and troublesome weeds have been introduced from Europe. A few have come from elsewhere. The question may be asked, why this fact is so? Before the natural conditions were much disturbed by white men from Europe, eastern America was a densely forested country in which most of the herbaceous plants grew on the forest floor in the shade of the dominant forest trees. When the forests were removed, these ground plants of the woods were subjected to the action of the full sunlight, to the drying effects of the wind, and to a soil deprived of its superficial layers of water-retentive leaf mold. They, therefore, were destroyed in large numbers of species, except the more hardy forms which adjusted their growth to the new conditions. The introduced plants, removed from the inhibition of their European competitors, insect and fungous foes and accustomed for at least a thousand years to open field cultivation and growth along roadsides and other open places, found the new environment favorable to their rapid spread and occupancy of the soil vacated by the native species of plants. It has been suggested also that the European species were more plastic than the native American plants and better able to adjust their growth to their new surroundings. Some of the weeds, however, came from the west, but were introduced later than the advent and spread of the overseas army of weeds. These western weeds came in when the cultivated areas were extended westward beyond the forested areas, so as to occupy the open prairie and steppe country to the westward. Opportunity was thus presented for the native plants of the prairies and steppes bordering on the cultivated districts to contribute somewhat to the weed flora of the east, because with the plowing of the land these western weedy plants found the conditions very favorable for their eastern spread, such as the carpet weed (*Mollugo verticillata*), daisy fleabane (*Erigeron canadensis*), cocklebur (*Xanthium*), rag weed (*Ambrosia artemisiæfolia*), vervain (*Verbena hastata*, *V. urticifolia*), horse nettle (*Solanum carolinense*) and others. Of late and in consequence of increased communication with the prairies and the country beyond the Mississippi River, the western plants are moving eastward by rapid strides. Such are fetid marigold (*Dyssodia papposa*), pineapple weed (*Matricaria suaveolens*) and wormwood (*Artemisia biennis*). Ninety years ago the black-eyed susan (*Rudbeckia hirta*) flourished from the Alleghany mountains westward, but was unknown in the east. Now since about 1860, it has become an abundant and conspicuous weed in grass fields throughout the eastern states, as far as the Gulf of St. Lawrence, having been accidentally introduced in red clover seeds from the western states. The velvet leaf (*Abutilon Theophrasti*) and prince's feather (*Polygonum orientale*) have been introduced from India. The bur clover came to California from South

FIG. 100.—Russian thistle (*Salso kali var. tenuifolia*) as a tumbleweed at Akron, Colorado. (*G. E. Nichols*, 1913.)

America. The orange hawk weed (*Hieracium aurantiacum*) was grown from imported European seed by the aunt of the botanist, Cyrus G. Pringle, in Charlotte, Vermont about 1845. The plant was much admired and sent to friends in Maine, Massachusetts and Vermont, according to Prof. Geo. P. Burns. It was cultivated in some gardens of Maine under the name of tassel-flower, or Venus's paint-brush. It propagates very freely by runners, as well, as by feathery fruits. It is now spread over large areas of Maine and other New England states, in northern Pennsylvania, as at Eaglesmere, where a field of it was noted by the writer in full bloom on June 22, 1905.

Means of Distribution.—When once introduced, weeds migrate in a number of ways by natural and artificial means. The natural migration of weeds is favored by the possession of runners (slender radiating branches), by elongating rootstocks, by running roots, by seed-throwing apparatus, by having fleshy edible fruits with hard seeds, by flying seeds, and winged fruits, by drifting over frozen ground, or snow, as tumble weeds, (Fig. 100), by means of water-carried seeds, by attachment to the hair and fur of animals by means of hooks and other devices. The artificial means are as follows: Roots, rootstocks and bulbs are sometimes carried from field to field and from farm to farm by plows, harrows and

Fig. 101.—Extensive patch of bouncing bet (*Saponaric officinalis*) along an unused railroad siding across Hackensack Meadow, July 15, 1916.

cultivators. Seeds and other plant parts are carried away in the ball of earth surrounding the roots of nurserystock. They are entangled in packing material, in the waste from woolen mills, as the storksbill (*Erodium*), in hay, in commercial seeds, which is one of the most frequent ways of weed introduction. Weeds are carried along by the disturbance of the air through the passage of trains (Fig. 101) and automobiles and on these rapid means of conveyance. Weeds have been introduced as useful or ornamental plants which have later escaped from cultivation. They have been introduced in ballast and along with the packing of commercial articles.

Lines of Travel.—The lines of travel of weeds are of interest. The chicory was introduced into the United States near Dorchester, Mass. in 1875. It is a common weed in western Long Island, eastern Pennsylvania, although of recent introduction there, and in the northern states. The water hyacinth (*Eichornia crassipes*) was introduced into the St. Johns' River in Florida in 1890. It has spread southward and westward through the state along the river courses, so as to choke them and impede navigation. The cardoon (*Cynara cardunculus*) introduced into Argentina from Europe covers the pampas for miles. The introduced redtop follows the abandoned wagon tracks across the otherwise unbroken prairie for miles.

Special Weed Examples

Goose-Grass (*Eleusine indica*).—This coarse grass came to us from India and seems to be thoroughly domesticated. It grows from clustered, fibrous roots and forms spikes in digitate clusters at the end of the stalk. It grows as a weed in yards and waste places. It can be controlled in lawns by squirting a few drops of crude carbolic acid into the heart of a tuft with a common machine oil-can, which treatment ought to kill it.

Field Sorrel (*Rumex acetosella*).—The sheep sorrel has extensively creeping rootstocks with tufts of feeding roots. The radicle leaves are halberd-shaped and from their midst arises the flower stalk bearing male and female flowers on separate plants (*diœcious*). Sorrel can be controlled by cultivating the soil and adding lime to correct its acidity (Fig. 102).

Russian Thistle (*Salsola kali* var. *tenuifolia*).—This chenopodiaceous plant was introduced into the Dakotas and Minnesota in flax seed from Russia. It is a pernicious weed in grain fields and spreads itself as a tumble weed, scattering its seed, as it rolls over the ground blown about by the wind (Fig. 100). It can be controlled by sowing only clean seed and in cutting down the weed before it is allowed to seed. It then dies a natural death.

Chickweed (*Cerastium arvense*).—This is a pestiferous weed in alfalfa fields in eastern Pennsylvania and elsewhere. It is a winter annual with densely tufted stems, opposite, linear-oblong leaves and white flowers with bifid petals. It is difficult to eradicate unless a rotation of crops is practised, the alfalfa, or grass crops invaded by chickweed being alternated with hoed, or cultivated crops.

Purslane (*Portulaca oleracea*).—This is a bad weed in gardens (Fig. 103). The experiments of W. J. Beal show that the seeds retain their

FIG. 102.—Sheep sorrel (*Rumex acetosella*). A common weed in pastures and meadows, from Europe. (Division of Bot., U. S. Dept. of Agriculture.) (*Reproduced in Pammel, L. H.: Some Weeds of Iowa, Bull.* 70 *Experiment Station, Iowa State College,* 1903, *p.* 348.)

vitality in the soil for thirty years. It spreads over the ground with thick, alternate, obovate leaves. The small, black seeds are produced in small capsules, whose tops fall off as a lid. Hoeing up while in the seedling stage seems to be the only way of vanquishing this weed. Plants hung up to dry for a month, if returned to the soil, will begin their growth afresh, so that the hoed plants should be placed on the compost heap where fermentation will destroy the plants and the vitality of the seeds.

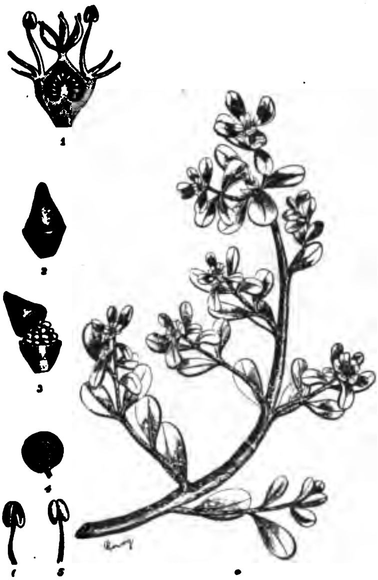


FIG. 103.

FIG. 104.

FIG. 103.—Pusley (*Portulaca oleracea*). An abundant garden weed. (Division of Bot., U. S. Dept. of Agriculture.) (*Reproduced in Pammel, L. H.: Some Weeds of Iowa, Bull.* 70, *Experiment Station, Iowa State College*, 1903, *p.* 358.)

FIG. 104.—Shepherd's purse (*Capsella Bursa-pastoris*). Common everywhere in northern United States. (Division of Bot., U. S. Dept. of Agriculture.) (*Reproduced in Pammel, L. H.: Some Weeds of Iowa, Bull.* 70, *Experiment Station, Iowa State College*, 1903, *p.* 364.)

Shepherd's Purse (*Capsella bursa-pastoris*).—This is probably the most widely distributed weed on earth. It develops a rosette of tufted, pinnatified leaves and an erect raceme of small, white flowers and later triangular flat silicles. This weed gradually succumbs to constant tillage, and when young, it is killed by a spray of copper or iron sulfate (Fig. 104).

Common Evening Primrose (*Oenothera biennis*).—This stout biennial plant with a rosette of lanceolate, basal leaves, and tall, leafy-bracted spikes of bright-yellow flowers, is a common weed in some places. It may be controlled by cutting the crown of leaves from the tap root with spud, or hoe, in the first season of its growth from seed. Plants with capsules fully formed should be burned.

Wild Carrot (*Daucus carota*).—This is perhaps one of the most common weeds in the eastern states, for in summer fields are white with its flowers produced in large spreading umbels. The crowns of twice to thrice pinnate leaves are produced the first season. Hand-pulling, as practised by some

Fig. 105.—Horse nettle (*Solanum carolinense*), a perennial weed. (Division of Bot., U. S. Dept. of Agriculture.) (*Reproduced in Pammel, L. H.: Some Weeds of Iowa. Bull.* 70, *Experiment Station, Iowa State College*, 1903, *p.* 316.)

of the farmers on Nantucket, is a rude method of extermination, provided the pulling is done before the fruits mature. Cutting off the leaf crowns with the hoe is also efficacious. In cultivated ground when the cultivator is used it gives little trouble, because it is usually uprooted the first season of its growth, being a biennial.

Viper's Bugloss (*Echium vulgare*).—This weed has established itself in the limestone soils of the Lebanon, Cumberland and Shenandoah valleys, where it is extremely common and troublesome. It is known, as Paterson's Curse, in Australia. It is a biennial arising from a thick taproot and with rough, bristly hairy stems and leaves. The stiff bristles arise from fine red, tubercles which speckle the stem. Hoeing, or the use of the cultivator the first season of its growth, is beneficial, if no seeds are allowed to form.

Horse Nettle (*Solanum carolinense*).—The deep-seated rootstocks are most tenacious of life (Fig. 105). An Indiana farmer states that they will live ten years under a heap of sawdust and grow, as soon as this covering is removed. Sheep are the only grazing animals that will touch the plant. The trailing stems and broad leaves of the plant are charac-

FIG. 106.—Two specimens of Ox-eye daisy (*Chrysanthemum Leucanthemum* var. *pinnatifidum*) in a sand-lot at Belmar, N. J., June 23, 1919. The right hand plant had a spreading habit with stiff, stout bluish-green stems margined with purple lines. It had 79 compact heads with crowded rayflowers of medium length. The left hand plant, a third taller than the other, was of a light green color with broader heads, the ray florets narrower, longer and more pointed. The stems were less stout, more flexuous and the whole plant with 76 head-bearing stems. These are probably mutants of the common field daisy.

terized by sharp yellow prickles. The flowers with pale-violet, rotate corollas are borne in open cymose clusters. It forms a small, yellow berry full of flat straw-colored seeds. If the area where it grows is not large, it may be killed by the use of hot brine, caustic soda, or kerosene. The production of seeds should be prevented and the plants frequently cut up with hoe, or spade. Salt on the cut surfaces will retard growth. The rootstocks may be destroyed by short rotations, alternating thoroughly cultivated crops. Two or three seasons of continuous effort are required to suppress this pest.

Yellow Toad-Flax (*Linaria vulgaris*).—The deep, running rootstocks of this weed make it difficult to suppress. The plant grows about eighteen inches tall beset with narrow, linear, alternate leaves. The flowers are labiate, spurred and yellow in color produced through the summer. The capsule is ovoid, two celled and filled with fifty to sixty flattened rough, wing-margined seeds. Small areas of this weed may be controlled by strong herbicides such as hot brine, or caustic soda. The use of a cultivator tends to spread the weed. Hoes and hand labor are more effective. Persistent cutting will cause the rootstocks to starve to death.

FIG. 107.—Ox-eye daisy (*Crysanthemum leucanthemum*). Common in the East. (Division of Bot., U. S. Dept. of Agriculture.) (*Reproduced in Pammel, L. H.: Some Weeds of Iowa. Bull.* 70 *Experiment Station, Iowa State College*, 1903, *p.* 337.)

Ox-eye Daisy (*Chrysanthemum leucanthemum pinnatifidum*).—The stems of white daisy are tufted from one to three feet high bearing a head of flowers with white marginal ones and yellow disc florets. The root leaves are in a rosette and are spatulate, pinnatifid. The achenes, which are found as an impurity in nearly all grass seeds, are grayish-black and finely ribbed without peppers. Clean seed only should be sowed. The daisy field can be cleansed by short rotations, as the perennial roots are turned out and killed by the plow. Mowing infested fields before the heads develop is another useful means of extermination (Figs. 106 and 107).

Canada Thistle (*Cirsium arvense*).—Nearly all of the states have laws which make it an offense for their citizens to permit this weed to mature and scatter its seeds. It is a perennial propagated by seeds and rootstocks. The map shows its range (Fig. 108).

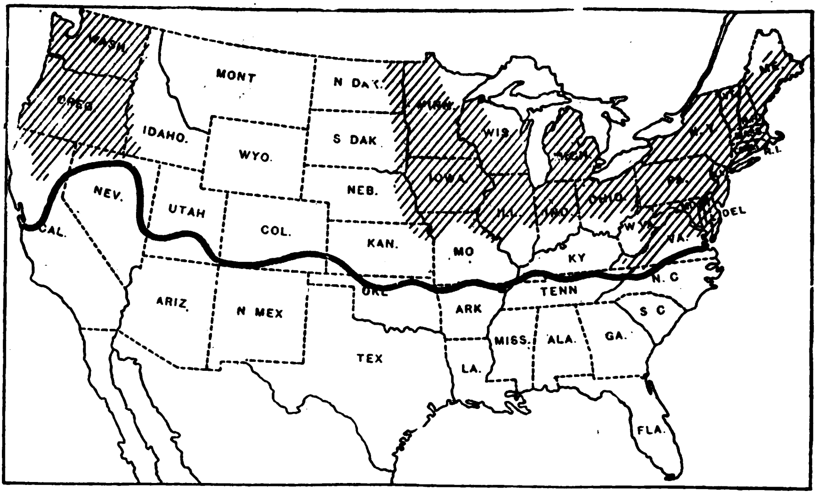


FIG. 108.—Map of the United States, showing the present distribution of the Canada thistle. The heavy line indicates the approximate southern boundary of the weed; the shaded area shows where the plant is most injurious. (*After Hansen, Albert A.: Canada Thistle and Methods of Eradication. Farmers' Bulletin* 1002, 1918, *p.* 5.)

Classification of Weeds

Weeds are conveniently classified according to the duration of their underground parts into:

1. Annual weeds, or those which complete their growth and mature their seeds in one year. Such plants are easily destroyed by cultivation. Here belong ragweed, crabgrass, purslane, pigweed and Russian thistle.

2. Winter annuals. These plants drop their seeds in the fall which germinate and give rise to plants which hold through the winter, finally producing flowers and seeds in the spring. Such are the chickweed and shepherd's purse. Here also is the prickly lettuce and dead nettle.

FIG. 109.—Mullein (*Verbascum thapsus*) in sandy field at Bayville, northern shore of Long Island, July 9, 1919. An unusually thrifty plant.

FIG. 110.—Field of Mullein (*Verbascum thapsus*) near Lake Mombasha, N. Y., July 30, 1914.

3. Biennials. The plants of this class expend their energy the first season in forming a root system and foliage leaves. The second year flowers are formed and the seeds are matured. The burdock (*Arctium lappa*), the sweet clover (*Melilotus alba*), the wild carrot (*Daucus carota*), the mullein (Figs. 109 and 110), and the teasel belong here.

4. The fourth class includes the perennial weeds, which perennate by means of roots, rootstocks, bulbs, tubers and other underground perennating organs. A number of our noxious weeds are propagated by running, or creeping roots, such as, milkweed (*Asclepias cornuti*), bindweed

FIG. 111.—Clump of dandelion (*Taraxacum officinale*) on a sand lot at Belmar, N. J., June 23, 1919. The clump was one foot high with 213 leaves and 40 head-bearing scapes.

(*Convolvulus arvensis*), sheep sorrel (*Rumex Acetosella*), Indian hemp (*Apocynum cannabinum*) and pasture thistle (*Cirsium*). Many weeds are propagated by subterranean stems or rhizomes. The list includes quack grass (*Agropyron repens*), poison ivy (*Rhus radicans*), morning glory (*Convolvulus sepium*).

5. Crown weeds. These have usually a deeply penetrating tap root, which produces shoots around its margin, when cut off close to the ground by a lawn mower, or mowing machine. The dandelion (*Taraxacum officinale*, (Fig. 111) ribgrass (*Plantago lanceolata*), curled dock (*Rumex crispus*) are crownweeds.

Destruction of Weeds

The destruction of weeds may be accomplished in a number of ways. All of these are based on a scientific study of the vitality, morphological structure and growth of the common weeds of farm and garden. The following are the approved methods of controlling and exterminating weeds.

1. It is important to prevent the production of seeds in the attempt to control weeds. It has been shown that some weed seeds have great vitality. De Candolle, who first carried on experiments along this line, showed this is especially true of the seeds belonging to the families *Leguminosæ* and *Malvaceæ*. Becquerel later studied the vitality of seeds and he found that of 550 species investigated by him that the age of the seeds varied from 125 to 135 years and that a few of the old seeds especially of the pulse and mallow families germinated on trial. Ewart found that 6 per cent. of the seeds of the common Indian mallow germinated after the lapse of 57 years and seeds of the white clover after 77 years and chicory after 10 years. The most noteworthy experiments were performed by Prof. W. J. Beal of the Michigan Agricultural Experiment Station in testing the vitality of seeds at intervals of five, ten, fifteen, twenty, twenty-five years. The seeds were placed in sand in bottles slanting downward so that water could not enter. These bottles were buried in the soil twenty inches below the surface. The following seeds germinated on each of the trials separated by five year intervals up to the twenty-fifth year. *Amaranthus retroflexus*, *Brassica nigra*, *Capsella bursa-pastoris*, *Lepidium virginicum*, *Anthemis cotula*, *Oenothera biennis*, *Polygonum hydropiper*, *Portulaca oleracea*, *Rumex crispus*. *Stellaria media*. *Verbascum thapsus*. Success in exterminating weeds, where the seeds retain their vitality for twenty-five years in the soil, is only the result of eternal vigilance in preventing seed production.

2. Weeds should be cut repeatedly, so as to exhaust the reserve supplies of food stored in the underground parts. The underground parts are thus starved to death.

3. The soil should be cultivated intensively so as to root up and destroy the growing weeds.

4. The ground should be occupied by some cover crop which by the density of its growth will crowd out the weeds. Larger heavier crops mean fewer weeds.

5. The sugar cane crop in the Hawaiian islands was formerly invaded by troublesome weeds. These have been exterminated by covering the planted cane with thick felt paper, which smothers the weeds of the cane-fields, but permits the sharp points of the growing cane stems to push through into the sunlight. The paper used for this purpose was formerly imported into the islands, but is now manufactured out of the fiber obtained from the sugar cane stems, that have been through the sugar mills and from which the sugar has been extracted.

6. Soils are sometimes sour and as a consequence have a particular weed flora, which will disappear, if the land is judiciously treated with lime.

7. Some weeds flourish in a wet soil, so that thorough drainage of such soils will lead to the disappearance of the troublesome plants.

8. The farmer should take the precaution of buying only pure seeds and in having those seeds tested (see next chapter), as many weeds are introduced by the sowing of agricultural seeds containing a considerable number of weed seeds.

9. It has been suggested without any trial on a large scale that weeds might be exterminated by inoculating them with pure cultures of destructive parasitic fungi. As possible fungi for trial may be mentioned the rust of Canada thistle (*Puccinia suaveolens*) and the spot disease of smart weed (*Septoria polygonum*).

10. The application of chemical herbicides has been tried successfully in some cases.

Common Salt (*Sodium chloride*).—This is the cheapest, handiest and safest of herbicides.

Copperas (*Iron sulfate*).—This chemical is comparatively cheap and as an herbicide. It should be used as a spray.

Bluestone (*Copper sulfate*).—This is used in solution of twelve pounds of copper sulfate to a barrel of water (52 gallons).

Carbolic Acid (*Phenol*).—This, because of its cost, can be used only in small areas.

Caustic Soda (*Sodium hydrate*).—This is better than carbolic acid for killing poison ivy.

Corrosive sublimate (*Mercuric bichloride*).—One ounce of chemical to six gallons of water.

Arsenite of Soda.—A very active poison used in a solution which is sprayed on the plants.

11. There are several other precautions which should be taken in the control of weeds. One of these is care to prevent the introduction of weeds in the manure used as a fertilizer and in the hay and straw brought on to the farm.

12. Pasturing weed infested fields will help to keep the weeds in check, especially, if sheep are allowed to browse in the weedy pastures. Goats are more omnivorous than sheep.

13. The open fields may be burned repeatedly, when the herbage is dry, and this annual conflagration aids in keeping the weeds in check.

Weed Legislation

Weed destruction and control requires individual and collective, or communal effort. This arises from the manner of the dispersal of weed seeds. If one farmer neglects his farm and allows the weeds to get the mastery, his neighbors' fields will be covered by the dispersion of the weed seeds in all directions. This fact and the perversity of human nature necessitates that laws be made to control the weed problem of state or community. Many American states have adopted weed statutes. To be effective a weed law must be specific with respect to the weeds to be destroyed, while the dates assigned for work and the methods employed must be adapted to these plants. It must be open to change as to the plants named in the law, because there is the constant introduction of new and troublesome weeds. A weed law should furthermore, impose weed destruction in such manner as to lay the least burden, while at the same time fixing the responsibility upon the persons using the land, who are benefitted by it. A weed law must be operative. The careless user of land is often an offender. A definite officer should be charged with the supervision of such matters as may come within his purview.

Bibliography

American Writer: Weeds. Gardeners' Chronicle & Agricultural Gazette. 1873, 1419 (October, 18).

Beal, W. J.: Michigan Weeds. Bulletin 267 (Second Edition), Michigan Agricultural College Experiment Station, Botanical Department, November, 1915.

Cates, J. S.: The Weed Factor in the Cultivation of Corn. Bulletin 257, Bureau of Plant Industry, U. S. Department of Agriculture, 1912.

Cox, H. R.: Wild Onion: Methods of Eradication. Farmers' Bulletin 610, U. S. Department of Agriculture, 1914. Weeds: How to Control Them. Farmers'

Bulletin 660, 1915; Eradication of Ferns from Pasture Lands in the Eastern United States. Farmers' Bulletin 687, 1915.

DARLINGTON, WILLIAM: American Weeds and Useful Plants. Second edition, New York, Orange Judd & Company, 1859.

DEWEY, LYSTER H.: Weeds and How to Kill Them. Farmers' Bulletin 28, 1895. Legislation Against Weeds. Bulletin 17, Division of Botany, U. S. Department of Agriculture, 1896; Migration of Weeds. Yearbook of the U. S. Department of Agriculture, 1896, 263–286. Weeds and How to Kill Them. Farmers' Bulletin 28, second revision, 1905.

DUVEL, J. W. T.: The Vitality of Buried Seeds. Bulletin 83, Bureau of Plant Industry, 1905.

FERNALD, M. L.: Some Recently Introduced Weeds. Transactions Massachusetts Horticultural Society, 1905, Part I, pages 11–22.

FORSYTH, ALEX: Weeds. Gardeners' Chronicle, new ser., viii, 408, Sept. 29, 1877.

GEORGIA, ADA E.: A Manual of Weeds. New York, The MacMillan Company, 1914.

GRAY, ASA: Weeds. Gardeners' Chronicle, new ser., xii, 423, 455, Oct. 4, 1879.

HANSEN, ALBERT A.: Canada Thistle and Methods of Eradication. Farmers' Bulletin 1002, 1918.

HASKELL, S. B.: Vitality of Buried Seed. The Country Gentleman, March 17, 1917.

HENKEL, ALICE: Weeds Used in Medicine. Farmers' Bulletin 188, 1904.

HILLMAN, F. H.: Nevada Weeds. Bulletins 21, 22, 1893, 38, 1897, University of Nevada, Agricultural Experiment Station.

LITERARY DIGEST: A Crop that Makes its Own Weed Killer. May 18, 1918, page 22.

PAMMEL, L. H.: Weeds of the Farm and Garden. New York, Orange Judd Company, 1911. The Weed Flora of Iowa. Bulletin 4, Iowa Geological Survey, 1918.

PIPAL, F. J.: Wild Garlic and Its Eradication. Bulletin 176, Purdue University Agricultural Experiment Station, 1914. Red Sorrel and Its Control. Bulletin 197, 1916; Rabbit-proof Plants, List of. The Garden, I, 9, Nov. 25, 1871.

SELBY, A. D.: A First Ohio Weed Manual. Bulletin 83, Ohio Agricultural Experiment Station, 1897.

WILLIS, J. J.: Vitality of Seeds Buried in the Soil (review of the work of W. J. Beal). Gardeners' Chronicle, new ser., xxv, 757, June 12, 1886.

WOODSTOCK, CHARLES M.: To Eradicate Moss from Grass-land. Gardeners' Chronicle & Agricultural Gazette, 1869, 671–72 (June 19).

Suggestion to Teachers.—Teachers should have made collections of a number of the principal weeds and weed seeds, also illustrations of the same for class demonstrations. An attempt should be made to make an herbarium and set of dried weeds of the local flora, as the weed flora varies in different parts of the world.

LABORATORY EXERCISES

1. Describe the dried or fresh specimens of the weeds handed to you making floral diagrams of the flower parts.

2. Examine the fruits and seeds of a number of leguminous plants with especial reference to the structure, method of dehiscence and arrangement of seeds.

3. Draw and study in detail the seeds of a few of the above plants, or any good substitutes.

CHAPTER 18

AGRICULTURAL SEEDS, SEED SELECTION AND TESTING

General Considerations.—As the success of agricultural and horticultural operations, next to the preparation of the soil and a propitious climate, depends upon the character of the seeds which are sown, it is obvious, that for the seeding of the crop, the best seed is not good enough. With the seed sown to produce a given crop, if great care is not exercised in the selection of the seed, may go along weed seeds, the eggs of destructive insects and the spores of destructive fungi. Hence, the farmer must be constantly on the alert to see that his seed is pure and without these objectionable concomitants. If the farmer does not select and test the seeds himself, he must delegate that work to another person, who as a trained botanist, is connected with some central seed control station maintained by a Cooperative Farmers' Association, or by the Agricultural Experiment Station maintained by the state, or the national government. The seeds, which are purchased for use, will have been passed upon by the specialists before they are planted by the farmers. This has given rise to pure seed acts by a number of the states, by the national government, and by the Canadian government looking to the control of the seeds which are purchased for use in the raising of the crops upon which the prosperity of the states depends.

History.—The idea of controlling the quality of seeds offered for sale in the market by scientific methods was put into operation at the first institution for testing commercial seeds established at Tharandt, Germany, in 1870 by Dr. Friedrich Nobbe, who published in 1876 a compendious treatise "Handbuch der Samenkunde" later to be followed in 1885 with "Landwirthschaftliche Samenkunde" by Dr. C. D. Harz, a work of 1362 pages, published in two volumes. Other European stations were established and in 1877 the Connecticut Station began the testing of seeds. Omitting a consideration of the laws for seed control upon the statute books of the different states, reference to the more important available pamphlets on such laws will be found in the bibliography for this chapter, and we are free to proceed with a discussion of practical seed testing.

Apparatus for Seed Testing.—Most seed control stations have elaborate apparatus, which is used in the scientific study of the seed control problems. Such apparatus is described in various bulletins and textbooks enumerated below and need not be described in detail here. The following apparatus is recommended for use in making purity and germination tests.

Purity Tests

1. A chemical balance, weighing up to 100 grams and sensitive to 1 milligram, with accurate metric weights.
2. A seed mixer and sampler.
3. A nest of small copper sieves.
4. A vertical air-blast seed separator.
5. A reading glass mounted on a stand.
6. A hand lens, magnifying from 10 to 16 diameters.
7. A standard dissecting microscope.
8. Botanical forceps and dissecting instruments.
9. An authentic collection of the seeds of the principal weeds and cultivated plants.

Germination Tests

1. Standard, or Semper's germinating chambers, equipped with low-temperature thermostats and thermometers.
2. Blue blotting paper and canton flannel.
3. Sterilized sifted sand and shallow greenhouse flats.
4. Forceps.
5. Blank Forms for Record and Report.

Ordinarily such elaborate apparatus is not necessary for the simple experiments that a farmer ought to make in testing his seeds. He ought to have two dissecting needles, a small scalpel, a pair of forceps, a hand lens magnifying 16 diameters, a small chemical balance, a small graduated cylinder holding about 100 cubic centimeters, a dinner plate, a small bell jar, and several mats made by sewing squares of blotting paper between two pieces of canton flannel.

Practical Seed Testing

There are four fundamental points to be considered in practical seed testing. They are:

1. Whether the seeds belong to the species which it is desired to plant.

2. Whether the sample is free from deliberate adulterations and from noxious weed seeds and other noxious impurities.

3. Whether the sample possesses a high percentage of viable seeds and high vital energy, as shown by the rapidity with which germination takes place.

4. Whether they are of at least average volume-weight.

In determining the first point, whether the seeds belong to the species which it is desired to plant, a selected sample is spread out upon a piece

FIG. 112.—Mixture of weed seeds commonly found in low-grade alsike clover seed: *a*, alsike clover; *b*, white clover; *c*, red clover; *d*, yellow trefoil; *e*, Canada thistle; *f*, dock; *g*, sorrel; *h*, buckhorn; *i*, rat-tail plantain; *k*, lamb's quarters; *l*, shepherd's-purse; *m*, mayweed; *n*, scentless camomile; *i*, white campion; *p*, night-flowering catch-fly; *q*, oxeye daisy; *r*, small-fruited false flax; *s*, cinquefoil; *t*, two kinds of peppergrass; *u*, catnip; *v*, timothy; *x*, chickweed; *y*, Canada bluegrass; *z*, clover dodder; 1, mouse-ear chickweed; 2, knot-grass; 3, tumbling amaranth; 4, rough amaranth; 5, heal-all; 6, lady's-thumb. (Enlarged.) (*After Hillman, F. H.: The Adulteration of Forage-Plant Seeds. Farmers' Bulletin* 382, 1909, *p.* 10.)

of white paper and the seeds gone over one by one (Fig. 112). All foreign seeds, if any are present, are removed and later weighed. The percentage obtained by weighing will give the purity of the sample. In purchasing seeds in the market, we cannot expect to obtain the highest possible quality, or 100 per cent. of real worth. One hundred per cent. is the ideal standard of measurement and at best we can only hope to approximate it. Agricultural seeds, 99 per cent. pure, may be considered to be very high grade seeds, for with improved methods of farming, improvement in the purity of seeds is very rapid.

The second point is determined in the same way, only particular attention is given to the removal of the weed seeds, which may be mixed in the sample. After all the weed seeds and other impurities are removed, their weight is taken and we can then determine the percentage of weed seeds present in the sample. The seed specialist goes further than this and determines the particular kind of weed seeds which are present. Constant practice and a knowledge of the different kinds of seeds will enable him in many cases to determine what seeds are present, but occasionally seeds are found, which he is unable to identify. The botanist then has recourse to illustrations and to the collection of seeds, which all well equipped seed laboratories have amassed for the purposes of such comparison. Unless the seed is of an unusual kind, the identification can be made quickly with such aids at hand. Inert matter in some seed tests are included in the final statement, as to the seed impurities. Inert matter includes dirt, stones, chaff, sticks and the like. One of the best laboratories of its kind in the United States is maintained by the Colorado Agricultural Experiment Station at Fort Collins, Colorado. The findings of the seed specialist there, as to the chief weed seeds in Colorado crop seeds, may be taken as a sample of the kind of work done in the testing of seeds taken from the Second Annual Report of the Colorado Seed Laboratory for 1918.

The chief weed seeds in Colorado crop seeds are: Wild oats, black bindweed, rough pigweed, lamb's quarters, sunflower, field sorrel, Russian thistle, and green foxtail. Other common weed seeds are wild mustard, Indian mustard, buckhorn, red-stemmed plantain, cow cockle, slender wheat-frass, prostrate pigweed, common ragweed, sedge, large mouse-eared chickweed, fetid marigold, barnyard grass, gumweed, peppergrass, witch grass, spotted smartweed, five-finger, curled dock, pigeongrass, and buffalo bur.

There were 188 different kinds of weed seeds occurring as impurities in crop seeds.

The analyses show the following most common impurities of the important crop seeds sold in Colorado.

Alfalfa.—Indian mustard, dodders, prostrate pigweed, tall pigweed, lamb's quarters, barnyard-grass, sunflower, gumweed, sweet clover, witch-grass, curled dock, Russian thistle, and green foxtail (Figs. 113 and 114).

Barley.—Wild oats, black bindweed or wild buckwheat, and sunflower.

Blue-grass.—Peppergrass, sour sorrel, chickweed, and sedges.

Cane.—Russian thistle.

Millet.—Tall pigweed, ragweed, lamb's quarters, sunflower, Russian thistle, smartweed, green foxtail, yellow foxtail.

FIG. 113.—Alfalfa of good quality. Natural size and magnified 9 times. (*After Brown, Edgar and Crosby, Mamie L.: Imported Low-grade Clover and Alfalfa Seed. Bull.* 111, *Part III, Bureau of Plant Industry,* 1907).

FIG. 114.—Imported alfalfa of low grade. Natural size and magnified 9 times. (*After Brown, Edgar and Crosby, Mamie L.: Imported Low-grade Clover and Alfalfa Seed. Bull.* 111, *Part III, Bureau of Plant Industry,* 1907.)

Oats.—Wild oats, black bindweed or wild buckwheat, lamb's quarters, sunflower, and Russian thistle.

Red Top.—Rugel's plantain, yarrow, sedge, rush, and five-finger (Figs. 115 and 116.)

Sorghums.—Pigweed, ragweed, sunflower, and Russian thistle.

Sudan grass.—Tall pigweed, lamb's quarters, sunflower, Russian thistle, and buffalo bur.

Sweet Clover.—Slender wheat-grass, tall pigweed, lamb's quarters, sunflower, Russian thistle, and green foxtail.

Timothy.—Rugel's plantain, peppergrass, and sheep sorrel.

FIG. 115.—Red clover of good quality. Natural size and magnified 9 times. (*After Brown, Edgar and Crosby, Mamie L.: Imported Low-grade Clover and Alfalfa Seed. Bull.* 111, *Part III, Bureau of Plant Industry,* 1907).

The third point as to the vitality of the seeds, which the farmer proposes to purchase, can only be determined by an actual test of the power of germination of the seeds to be tested (Fig. 117). Some seeds, owing to the fact that the resting period has not been covered, refuse to germinate

FIG. 116.—Imported red clover of low grade. Natural size and magnified 9 times. (*After Brown, Edgar and Crosby, Mamie L.: Imported Low-grade Clover and Alfalfa Seed. Bull.* 111, *Part III, Bureau of Plant Industry,* 1907.)

when first planted, while other seeds, such as the clovers, will germinate twelve hours after the "harvest ripeness" stage occurs. In other cases sound and viable seeds are delayed in sprouting by an impermeable seed coat. In practical seed-testing, where one hundred, or more, seeds are placed in the germination chamber, or in a more simple way between the wet blotter pads on a dinner plate (Fig. 118) under a bell jar, the following times may be taken as the ones in which more than one-half the seeds used may be expected to sprout: The cereals, clovers, opium poppy, crucifers, spurry, vetchlings and peas—three days.

Cucurbits, beans, flax, spinach, buckwheat, rye, wheat and timothy grass—four days.

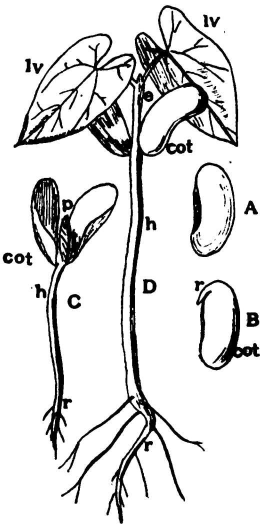


FIG. 117.

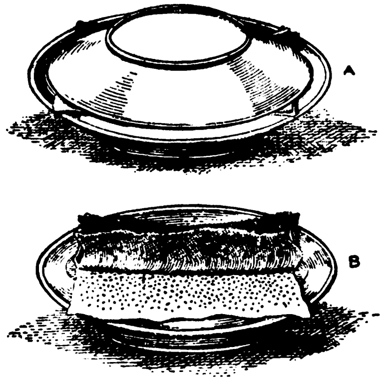


FIG. 118.

FIG. 117.—Seed and stages in germination of white bear (*Phaseolus vulgaris*). *A*. Seed with hilum; *B*, seed deprived of its coats. *C*, early stage of germination; *D*, later stage show epigeal cotyledons; epicotyl, hypocotyl and first foliage leaves; *r* = radicle; *h* = hypocotyl; *e* = epicotyl; *cot* = cotyledon; *lv* = first true leaves; *p* = plumule.

FIG. 118.—Homemade seed tester. *A*, closed: *B*, open. (*After Brown, Edgar and Hillman, F. H.: Seed of Red Clover and its Impurities. Farmers' Bulletin* 260, 1906, *p*. 8.)

Oats, tall oat grass, canary grass, maize, meadow fescue and ray grasses —five days.

Red top, sainfoin, beet, carrot (Fig. 119) and others—six days.

Meadow foxtail, yellow oat grass, sweet vernal grass, peas, orchard grass—seven days.

The volume-weight is obtained by weighing in the air the contents of a standard measure, such as, the bushel, or the hectolitre. This weight is more or less influenced by the shape and size of the seeds which permit them to form a more or less compact mass, and also by the shape of the vessel. Small sized, or withered seeds give a smaller volume weight than large plump seeds. The number of seeds in any measure increases with the volume weight and the weight of the individual seeds decreases in like ratio. With cereal seeds the absolute weight of the individual seeds invariably increases with the volume weight. Chemical analyses show that the higher the volume-weight ,the better the edible quality of cereal, or starchy seed. Hence it is important to determine the volume-weight.

To estimate the real, or agricultural worth of a seed sample, we must combine the purity and viability percentages, thus:

$$\frac{\text{Viability} \times \text{Purity}}{100} = \text{Real, or Cultural Worth in terms of per cent.}$$

Means of Detecting Source of Seeds.—It is important to have a reliable means of detecting the source of supply of seeds. Wittmack was

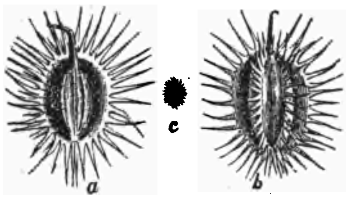


FIG. 119.—Wild carrot. *c*, natural size; *a*, *b*, front and edge views. (*Taken from Seed Testing its Uses and Methods, North Carolina Agricultural Experiment Station Bull.* 108, 1894.)

the first scientific man to interest himself in this question, and in 1873, he recognized a red clover as American owing to the presence in it of seeds of *Ambrosia*. Sometimes the appearance of the seed itself—the metallic lustre of its coat—proclaims its origin. Stebler calls those weed seeds which indicate the origin of the seed *source indicators*. Other seeds not as reliable, but still helpful, he calls *companion* seeds. Of the weed seeds found in red clover a few such as ragweed, spurge, field dodder, Bracted and black-seeded plantains, spiny sida, lady's thumb and vervain indicate the American origin of the seed in other words are *source indicators*. On the other hand clover dodder (Fig. 120), scentless chamomile, wild madder and ox tongue indicate imported seed. Stebler recognizes the following seed supplying districts of the world and the source indicators.

1. South European (South France, Italy, Spain). *Coronilla scorpioides* and *Ammi majus*.

2. West European (Great Britain, N. France, Netherlands). *Alopecurus agrestis*, *Carum petroselinum.*

3. North American (United States and Canada). *Panicum capillare*, *Cuscuta arvensis*, *Rudbeckia hirta*, *Ambrosia artemisæfolia.*

FIG. 120.—Mature dodder (*Cuscuta*) on an alfalfa stem. (*After Mairs, T. I.: Some Soiling Crops for Pennsylvania, Bull.* 109, *Pennsylvania State College Agricultural Experiment Station*, 1911, *p.* 13.)

4. Australian (Australia and New Zealand.) *Agrostis Fosteri*, *Danthonia semi-annularis.*

5. Asiatic (Syria, Turkestan). *Silene dichotoma*, *Saponaria vaccaria*, *Glaucium corniculatum*, *Berteroa incana*, *Erysimum orientale*, *Hibiscus trionum*, *Anthemis austriaca*, *Carduus acanthoides.*

6. South American (Chili. Argentine Republic) *Ceratochloa australis*, *Medicago denticulata*, *M. maculata*, *Melilotus parviflora*, *Ammi visnaga*, and *Cuscuta racemosa*.

Number of Seeds in Pound and Bushel.—The number of weed seeds sown with agricultural seeds is astonishing. In one sample, that contained in all only one-fifth of one per cent. of spurious seeds, the number of weed seeds per pound averaged 990. In a bushel of 60 pounds there were, therefore, more than 59,000 weed seeds. A sample of clover seed offered on the Chicago market in 1898 for two cents per pound contained 338,000 weed seeds per pound, or more than 20,000,000 per bushel. Hence, we are led to observe that low-priced seed may be expensive, when we consider, that it costs just as much to prepare the soil for poor seeds, as for good seeds, and if the seeds are poor the amount of labor later exerted in the extermination of the weeds more than offsets the initial expense of the seeds. Hence the farmer should grow the best seed that he can obtain on the market, even if the price is high.

Slowly, but none the less surely, America is becoming the recognized center of the world's seed-growing industry. The need, therefore, of men scientifically trained in all phases of this industry is important for the future development of the seed industry. Whoever contributes to the education of these men contributes to the welfare of the state.

Bibliography

American Agriculturist: Testing Seeds. Gardeners' Chronicle, new ser., viii, 268, September 1, 1877.

Beal, W. J.: Seeds of Michigan Weeds. Bulletin 260, Michigan State Agricultural College Experiment Station, March, 1910; Seed Dispersal. Boston, Ginn & Company, 1900.

Brenchley, Winifred E.: Buried Weed Seeds. Journal Agricultural Science, ix, I, 1–31, 1918; review in Journal Royal Horticultural Society, xliv, 164, May, 1919.

Brown, Edgar: Alfalfa Seed. Farmers' Bulletin 194, 1904.

Brown, Edgar and Hillman, F. H.: Seed of Red Clover and Its Impurities. Farmers' Bulletin 260, U. S. Department of Agriculture, 1906.

Clark, George H.: The Seed Control Act (Canadian). Bulletin No. S.1, Revised Edition, Dominion of Canada, Department of Agriculture, July, 1907.

Dailey, Arthur T.: Seed Separation and Germination. Facts for Farmers, iii, No. 9, May, 1913.

Duvel, J. W. T.: The Vitality and Germination of Seeds. Bulletin 58, Bureau of Plant Industry, U. S. Department of Agriculture, 1904.

Guppy, H. B.: Studies in Seeds and Fruits. An Investigation with the Balance. London, Williams and Norgate, 1912; Plants, Seeds and Currents in the West Indies and Azores. London, Williams and Norgate, 1917.

HARZ, DR. C. D.: Landwirthschaftliche Samenkunde Handbuch für Botaniker, Landwirthe, Gärtner, Droguisten, Hygieniker. Berlin, Verlag von Paul Parey, 1885.

HICKS, GILBERT H. and KEY, SOTHORON: Additional Notes on Seed Testing. Yearbook, U. S. Department of Agriculture, 1897, 441–452.

HILLMAN, F. H.: Dodder in Relation to Farm Seeds. Farmers' Bulletin 306, 1907; The Adulteration of Forage-plant Seeds. Farmers' Bulletin 382, 1909.

HUGHES, H. D.: The Germination Test of Seed Corn. Bulletin 135, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts, February, 1913.

JENKINS, E. H., HICKS, G. H. and OTHERS: Rules and Apparatus for Seed Testing. Circular 34, Office of the Experiment Station, U. S. Department of Agriculture, 1897.

JOHNSON, T. and HENSMAN, MISS R.: Agricultural Seeds and Their Weed Impurities: A Source of Ireland's Alien Flora. The Scientific Proceedings of the Royal Dublin Society, xii, new ser., 446, 462 with plates, July, 1910.

KRUHM, ADOLPH: Growing Seed for the World. The Garden Magazine, December, 1916, 164–16; The Romance of the Seeds. The World's Work, April, 1917.

LUBBOCK, SIR JOHN: A Contribution to our Knowledge of Seedlings (two volumes). New York, D. Appleton and Company, 1892.

McCARTHY, GERALD: Seed Testing, Its Uses and Methods. Bulletin 108, North Carolina Agricultural Experiment Station, 1894.

NOBBE, DR. FRIEDRICH: Handbuch der Samenkunde Physiologische Statitische Untersuchungen über der wirthschaftlichen Gebrauchswerth der land und forstwirthschaftlichen, sowie gärtnerischen Saatwaaren. Berlin, Verlag von Wiegandt, Hempel & Parey, 1876.

PIETERS, A. J.: The Farmer's Interest in Good Seed. Farmers' Bulletin 111, 1900; Red Clover Seed. Farmers' Bulletin 123, 1901; Seed Production and Seed Saving. Yearbook, U. S. Department of Agriculture, 1896, 207–216.

ROBBINS, W. W.: Colorado Seed Laboratory. Bulletin, Vol. 1, No. 1, The Colorado Seed Act, Sept., 1917; No. 2, First Annual Report, December, 1917; No. 3, Second Annual Report, December, 1918; No. 4, Colorado Pure Seed Law, August, 1919.

SASSCER, E. R. and HAWKINS, LOU A.: A Method of Fumigating Seed. Bulletin 186, U. S. Department of Agriculture, 1915.

SCHMITZ, NICOLAS: The Germination Test of Seed Corn. Extension Circular 71, The Pennsylvania State College, School of Agriculture and Experiment Station, February, 1918.

STONE, GEORGE E.: Seed Separation and Germination. Bulletin 121, Massachusetts Agricultural Experiment Station, February, 1908.

TILLMAN, O. J.: Purity and Germination of Agricultural and Vegetable Seeds Sold in North Carolina. The Bulletin of the North Carolina Department of Agriculture, Division of Botany, Vol. 32, No. 10, October, 1911.

TRUE, A. C.: Rules and Apparatus for Seed Testing. Circular 34 (revised), Office of the Experiment Stations, U. S. Department of Agriculture, 1906.

WEED, CLARENCE MOORES: Seed-travellers. Studies of the Methods of Dispersal of Common Seeds. Boston, Ginn & Co., 1899.

Laboratory Work

Suggestions to Teachers.—It is desirable, although probably not feasible on account of lack of time, for the students to make a collection of weed seeds. These can be kept in vials in the manner indicated in the laboratory work at the end of Chapter 12. A collection of forty-eight weed seeds, or twice that number, if two boxes of vials are used instead of one, will be very helpful in the identification of doubtful weed seeds.

The botanical laboratory, where agricultural botany is taught, might form an agricultural collection, such as is outlined in a bulletin issued by the College of Agriculture, Agricultural Extension Service, University of Missouri, Columbia, Missouri, November, 1915. An outline of the suggestions in Project Announcement No. 2 is given herewith.

Agricultural Collections for Laboratories

Farm Crops Laboratory Material

Mounted Laboratory Material

Sets

I. Types of wheat. Spikes and threshed grain.
II. Varietal types of common wheat.
III. Types of oats. Panicles and threshed grain.
IV. Types of barley. Spikes and threshed grain.
V. Types of clovers. Head and threshed grains.
VI. Sorghum types.
VII. Economic grasses. Spikes and panicles with threshed seeds.
VIII. Botanical types of corn.
IX. Varieties and types of millets.
X. Miscellaneous cereals.
XI. Seeds of miscellaneous forage, root, fiber and other plants.
XII. Pathological specimens of loose smut of wheat, covered smut of wheat, loose smut of barley, smuts of corn and oats, etc.

In addition to the above, there should be accumulated book illustrations, photographs, score cards and maps showing distribution and economic importance of the various crop plants.

The teacher should have on hand several pounds of commercial seeds purchased in the open market, such as alfalfa, red clover, wheat, rye and oats. These are accumulated for use in the following exercises.

Laboratory Exercises

1. Small measured quantities, either by volume, or by weight, of some seed sample (as above) should be distributed to every student in the class, who should make an analysis of the samples distributed. The good seeds should be placed in one pile, the weed seeds in another, and the impurities in a third. An estimate should then be made of the percentages of purity of each of the samples.

2. The weed seeds, separated as above, should then be identified by the use of illustrations and comparison with the laboratory collection of weed seeds.

3. Seeds, which germinate quickly (3–4 days), should be used for the purpose of testing the viability of seeds and learning the technique of the test. The simplest arrangement is to use the blotter pads previously described by placing alternately wet pads and layers of seeds between two deep soup dishes, one of them being inverted over the other (Fig. 118). The rag doll seed tester may also be used. Secure muslin cloth of a good quality and tear into strips from eight to ten inches wide and three to five feet long. Where these strips are to be used very much, the edges should be hemmed to prevent raveling. Squares can then be marked with a heavy pencil on the cloth, so that they have a three inch side. The seeds are then placed on the square and the cloth rolled up, so as to inclose the seeds. The whole roll is then placed in water for a few hours and then removed and kept moist until germination begins. In both of these methods of testing the germination of seeds, if one hundred seeds are used, the number that germinate within the specified time will give the exact percentage of viability without calculation.

GLOSSARY AND INDEX

No attempt is made to form a complete glossary of terms, but only those words are included which might give trouble to the reader of the book.

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